RURAL ENERGY DATABASE

Final Report

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CHAPTER 1

Introduction

1.1 Background

Like most developing countries, the fuel mix in the rural areas of India is characterized by the predominance of biofuels. Among these, fuelwood occupies a pre-eminent position by accounting for over half of the energy consumption (NCAER 1985). After food, the most pressing concern in the foreseeable future will be to provide energy for both, subsistence and economically productive activities in the rural areas of the developing countries. Substantially higher energy would be required for both, subsistence as well as economic development. A judicious choice of energy development path would be needed to meet the growing demand for energy, particularly for biofuels in rural areas, in a sustainable manner

Though the relationship between deforestation and the dependence of the rural population on fuelwood is a tenuous one,[1] there is little dispute regarding the fast deteriorating biomass resource base Combined with the inability of the people to shift to commercial fuels like kerosene[2] on account of low purchasing power[3] and limited availability, the rural people are facing what has been termed as the 'other fuel crisis'. With this background, providing energy to the rural areas without affecting the ecological sustainability will continue to be a formidable challenge.

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[1] Over 75 percent firewood consumed in rural areas is in terms of twigs and about 57 percent is collected at a zero private cost (NCAER 1985) In contrast, urban and industrial consumers account for the bulk of the log consumption -- in fact one school of thought (see Gadgil 1989) suggests that commercial interests are the major factor responsible for deforestation Furthermore the NCAER fuel survey (NCAER 1985) indicated that the felling of trees for fuelwood was an uncommon practice Furthermore, 60% of deforestation in developing countries is attributed to the expansion of agriculture (World Bank 1992) Linking deforestation *primarily* to rural energy consumption therefore, has little basis There is, on the other hand, evidence of practices of fuelwood extraction (such as lopping of young trees which destroys the middle stock) which degrade the biomass resource base Hence, careful studies of factors resulting in deforestation are required before causes can be attributed

[2] There has been a perceptible change in rural energy policy from the 1960s when the Energy Survey of India (ESI 1965) recommended (and visualized) a shift from biofuels to commercial energy (mainly kerosene) The Working Group on Energy Policy (WGEP 1979), for example, emphasized on the importance of biofuel supply augmentation increased efficiency of biofuel utilization (through improved cookstoves) and better deployment of technologies such as biogas in rural areas The Advisory Board on Energy (ABE 1985) and the Energy Demand Screening Group (EDSG 1986) essentially echoed the recommendation of the WGEP - the emphasis on the importance of commercial fuels such as kerosene and coal for the rural domestic sector was absent

Among the measures taken to address the perceived 'rural energy crisis' since the early 1980's were a large number of studies and surveys commissioned by the Government agencies for a better understanding of the rural energy demand. In 1979 the Working Group on Energy Policy (WGEP) had highlighted the rural energy issues and also brought forth the absence of data on biomass energy use. As a result, the Department of Non-conventional Energy Sources (DNES), Planning Commission, the Advisory Board on Energy (ABE), and various state energy development agencies commissioned rural energy surveys in different regions of the country. The objectives of these studies varied from estimating the energy consumption to developing integrated decentralized energy plans, the geographical coverage varied from a single village to a cluster of villages, block, district, state and regional etc.[4]

As a consequence of these and other studies, the qualitative aspects of the rural energy consumption have been reasonably well documented and are understood fairly well. However, the data collected in these studies, surveys reveal a large degree of variability and the quantitative understanding of the factors affecting the variability remains inadequate The insufficient understanding has made the task of aggregating and/or forecasting demand (both of which form crucial parts of energy planning) for the rural energy sector for the purpose of energy planning extremely difficult.

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[3] In addition to limited purchasing power, the expenditure pattern in rural areas is characterized by predominance of food items According to the National Sample Survey (44th Round of July - December 1988), of the total expenditure of Rs 172 per capita per month all India rural average, Rs 110 goes for food items The average expenditure on items classified as 'fuel and light is Rs 12 49 with the expenditure ranging from Rs 10 39 for the state of Andhra Pradesh to Rs 18 17 for the state of Punjab (see NSSO 1990 for details)

[4] The objectives the methodology the coverage and many other factors for large number of surveys were examined in a study by Joshi and Ramana (1989) They analyzed over fifty such micro-level survey reports spanning 750 villages containing about 30 000 households to evaluate the objectives, methodologies and the data presented in order to highlight the issues that needed consideration while designing further studies for understanding rural energy issues and for designing interventions in the rural energy sector The authors have examined the coverage of various studies, the methodologies adopted to select villages and households and to collect information The extent of information available in different studies on energy consumption and supply and the issues related to the use of the information in the planning process along with the elements of proposed plans were also examined

Furthermore, the access to the data collected in these surveys is limited due to absence of a compilation of all such surveys. Needless to emphasize, for an effective utilization of the collected data for various aspects of energy planning and to enhance understanding of the rural energy system it is necessary to compile and analyze the data generated so far. The computerization of this data base will permit a quick and easy access to the available information regarding the pattern and quantity of energy use under diverse agroclimatic and demographic conditions that prevail in India. In some cases, it may permit quick and inexpensive estimates of energy consumption and requirements for the purpose of designing effective intervention strategies. This study hopes to make a beginning in this direction.

1.2 Objectives and scope

The objectives of this study are

- ☐ to compile and analyze the data from the available rural energy surveys conducted during 1985-92 in India to create a comprehensive database,
- ☐ to attempt to establish, if possible, a causal relationship between the quantity and the pattern of energy consumption for an enduse in different agro-climatic regions
- ☐ to develop a micro computer based software for utilizing/updating the created database for estimating energy consumption and/or requirement for a village (or a cluster of villages).

Such a database can be utilized to carry out the following tasks

- ☐ identify regional variations in energy consumption pattern, energy resource base, etc., and arrive at regional norms for energy consumption. Working out such standard regional norms would decrease, or possibly, obviate the need for doing extensive energy surveys in future thereby saving significant time and money in the process of energy planning
- ☐ identify the lacunae, if any, in the present database so that a methodology can be developed to carry out future energy survey exercises The results of these surveys can strengthen the database so that all the relevant factors affecting energy consumption can be captured.

☐ provide means, through the developed software, of making estimates of energy consumption and/or requirements of the village (or a cluster of villages) without necessarily having to resort to time-consuming and expensive energy surveys. A more reliable and accurate method of aggregating energy demand in a region will be developed. An additional advantage would be the strengthening of energy planning capability of the nodal/state agency at the regional or other local administrative level.

The results of this study will comprise of

☐ a database which can be updated and which will facilitate quick and easy retrieval of relevant data,

☐ a micro-computer based software for estimating energy demand/requirement for a village (or a cluster of villages) based on available agro-climatic and demographic data.

Considering these objectives, in this chapter we first discuss some conceptual issues relating to energy demand. The methodology followed in this study is then outlined This chapter concludes with the outline of the present report.

1.3 Conceptual issues

The primary task in any discussion relating to energy demand estimation is to distinguish between energy *per se* and the service which the energy seeks to provide.[5] Thereafter, distinction should be made between energy requirement and energy consumption The energy requirement will depend on the purpose of the intervention. The requirement of energy would be different if quality of life is sought to be altered through interventions resulting in economic development and providing better services as opposed to interventions which maintain a status quo in these respects but seeks to alter the energy system in order to make it sustainable For subsistence needs the energy requirement is likely to require some normative assumption.

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[5] There is very little reason to belabour this point considering the extensive discussion and unanimity regarding this issue (see, for example, Goldemberg et al 1988 Goldemberg and Reddy 1990, Reddy et al 1990) We reiterate it here because appreciation of this distinction among those with energy supply organizations in India is not very common

Further, to analyze issues related to energy demand it is important to distinguish between three different elements of energy demand: *volume effects*, which are changes in the energy demand due to the expansion in the economy of the unit for which energy demand estimates are being made (which could include, but need not be restricted to, the changes in the number (population) of agents causing the demand), *structural changes* which are changes in energy demand due to structural changes in the unit for which the demand estimates are being made; and *efficiency effects*, or the efficiency with which energy is utilized within the economy.

In the context of the demand estimation for rural areas, nearly all estimates have considered only population changes in so far volume effects are concerned. This is partly because there is very little evidence of a correlation between energy consumption and income, even if it can be established that the benefits of economic growth percolate to rural areas Volume effects of the energy demand estimates and projection have, therefore, typically included changes in the population The lack of information on the structural changes and the likely impacts of such changes is even more acute and, for the time being, inclusion of these effects with any degree of accuracy appears unlikely

The task of aggregating energy demand and its forecasting in time presupposes an understanding of the factors influencing the energy demand Additionally, forecasting the energy demand demands a quantitative knowledge of the way these factors are likely to change over the time interval of the forecast Though the qualitative aspects of the rural energy consumption have been reasonably well documented and are understood fairly well, large degree of variability and inadequate *quantitative* understanding of the factors affecting the variability makes the task of aggregating and or forecasting demand of such energy systems extremely difficult To summarize in the absence of an understanding of the factors influencing energy demand, aggregating energy demand in the past has essentially used estimates (mean values) of per capita energy consumption based on surveys and the population and the forecasting was restricted to changes in the demand due to increase in population.

1.4 Outline of the study

In Chapter 2, the approach followed in preparing the database is explained The details of the level of information provided in the survey reports, area of surveys, year of survey etc of the selected studies are presented. The approach followed in compilation and validation of the survey data is also described and a list of variables on which the data is being compiled is explained. In Chapter 3, results based on the analysis of the data compiled for 638 villages in 17 states spread over all the 14 agroclimatic regions in the country are discussed. Annexures 1.1 and 1.2 list the salient features of the agro-climatic regions.

Chapter 2

Setting up the database

2.1 Methodology

Considering the quality of data presently available for rural areas and the resulting incomplete understanding of the complex nature of rural energy demand both, aggregating and forecasting energy demand, are likely to yield results of poor quality. Consequently, the conclusions originating from these exercises will have limited value It may be more meaningful, at least for the time being, to agree upon normative (desirable) levels of energy consumption based on agro-climatic conditions. Then a rural energy planning exercise should strive to meet this level of energy demand in an efficient and cost-effective manner At a first degree of approximation, the eating habits (and, therefore, the cooking energy requirement), the irrigation energy requirement and, to some extent, energy requirements for small- scale industries are all likely to be determined by the cropping pattern of an area Cropping pattern, in turn, is likely to have evolved in response to the agro-climatic conditions most influential of which would be the soil quality and the availability of water for agriculture These are the major variables for the classification of the agroclimatic regions in India by the Planning Commission (Planning Commission 1987) Hence, we propose to examine the data in different agro-climatic regions [1]

It is generally believed that these surveys have generated tremendous amount of data which can be used for a wide range of purposes -- from understanding the mechanisms of rural energy consumption patterns to the formulation of detailed intervention strategies. However, the actual use would depend on the quality and quantity (and hence the utility) of the data generated in these exercises and the ease of access to the database.

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[1] The hypothesis that energy consumption in different agroclimatic regions is different is a major hypothesis that we propose to examine in this study As is discussed in Chapter 3, the analysis of the data collated in this study indicate that the variation in the energy consumption in the different regions is statistically significant

It is hoped that the procedure adopted by this study will facilitate the closer examination of various aspects related to energy demand in the rural sector. The broad procedure adopted to fulfil objectives of this project were as follows.

1 All the available studies were collected with the help of DNES.

2 Preliminary step in identifying variables influencing energy demand and supply required identifying the nature and the scope of the information contained in the existing documentation of the surveys and thereafter identifying common variables which influence the energy consumption and the fuel mix. 56 variables, common to the majority of the survey reports examined were identified

3 A standard format was designed for collating the data from the survey reports incorporating the identified variables The information included general details of the villages, resource base (biomass and otherwise), occupational pattern and sectoral energy consumption [2]

4 The surveyed villages were then grouped on the basis of their agro-climatic zones. The name of the village, district, state, as well as the specific agro-climatic region can therefore be used as retrieval points for energy consumption levels in the developed data base.

5 The data thus segregated (on the basis of agro-climatic region) was analyzed to examine correlations and an attempt was made to establish causal relationships between the energy use and other available information in the survey reports Attempt were made to correlate the energy consumption with the demographic features etc of the village and to establish relationship(s) between these factors and the level of energy consumption [3]

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2 At the time of conceptualizing the study it was hoped that the sectoral energy consumption would include agricultural industrial and transport sectors along with the existing fuel-mix in these sectors in addition to details of energy consumption in the domestic sectors As will be discussed in detail in Chapter 3, limited information was available on the energy use in agriculture Very little information was provided in the survey reports for the other sectors

3 In the process, it was hoped that the regression relationships if statistically possible, between the level of energy consumption and agroclimatic variables, demographic characteristics and the resource endowments of a village could be developed As is discussed in Chapter 3, this is not possible with the present data base

6 On the basis of the analysis the likely range of energy consumption in different agroclimatic regions is worked out.

This database has been computerized and a software package (for the use on micro-computers) to facilitate easy retrieval and for updating the database has been designed. A User Manual for the use of the designed software has also been written and is provided separately. The software has been designed to permit quick, inexpensive and reasonably reliable estimates of the energy consumption (mean values along with the associated standard deviation) and energy consumption distribution.

2.2 Description of surveys

The reports of the studies supported by the DNES were collected and studies covering 638 villages were selected on the basis of the coverage of various sectors and the level of information provided. A statewise list of number of villages surveyed is presented in Table 2.2.1, the agroclimatic break-up is given in Table 2.2.2, and districtwise list is provided in Annexure 2.1. A sample report from each agency was screened and a list of (56) variables (see Annexure 2.2) was drawn for preparing data compilation format prior to computerization and analysis[4]

Over half of the survey reports included in the analysis were conducted in the period 1988-89 (Table 2.2.3). For 212 of the 638 villages, the date of the survey were not mentioned in the report[5] The extent of information on other parameters which are useful for the purpose of energy planning is summarized in Table 2.2.4 A note of caution, however, is required as far as the extent of information is concerned The format in which data is presented for specific items vary widely as a result of which in many cases it is not possible to computerize all of these. For example, though energy use in agriculture is provided for a little over half of the villages, some reports present data aggregated for the village as a whole and aggregated for all the crops. At the other extreme, some reports present crop-wise energy use (disaggregated for fuels along with break-up of animate energy used for different agricultural operations) for each village (for example, the ORG study for Wardha). Clearly, standard formats for such wide variety of data is of little use.

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[4] Data from reports from villages within a state was compiled into standard datasheets and computerized in the spreadsheet format (Lotus 1-2-3 version 2.2 and, later, QuattroPro version 3.0 were used for this purpose) These were then sorted according to the agroclimatic region (resulting in 14 spreadsheet files) The separate files were subsequently merged into a masterfile for analysis The statistical analysis was facilitated by SPSS PC+ (version 3.0)

[5] The relevance of the year of the survey is related to the comparability of the different survey data This comparability is particularly important when the fuel-mix is to analyzed for the different agroclimatic regions or for different demographic characteristics

Table 2.2.1. State-wise list of surveyed villages.

State	No of villages surveyed	Percent	Valid Percent	Cumulative Percent
Andhra Pradesh	33	5 2	5 2	5.2
Assam	15	2.4	2.4	7.5
Bihar	59	9 2	9 2	16 8
Gujarat	119	18 7	18 7	35 4
Haryana	61	9 6	9 6	45 0
Himachal Pradesh	4	6	6	45 6
Jammu & Kashmir	1	.2	2	45 8
Karnataka	29	4 5	4 5	50 3
Kerala	2	3	.3	50 6
Madhya Pradesh	14	2 2	2 2	52 8
Maharashtra	91	14 3	14 3	67 1
Orissa	67	10 5	10 5	77 6
Punjab		4	6	78 2
Rajasthan	69	10 8	10 8	89 0
Tamil Nadu	55	8 6	8 6	97 6
Uttar Pradesh	8	1 3	1 3	98 9
West Bengal	7	1 1	1 1	100 0
TOTAL	638	100 0	100 0	

Table 2.2.2. Agroclimatic zone break-up of surveyed villages

Code	Agroclimatic region	No. of villages surveyed	Percent
1	Western himalayan region	5	0.8
2	Eastern himalayan region	15	2.4
3	Lower gangetic plain	7	1.1
4	Middle gangetic region	33	5.2
5	Upper gangetic plains	2	0.3
6	Trans-gangetic plains	68	10.7
7	Eastern plateau and hill region	72	11.3
8	Central plateau and hill region	51	8.0
9	Western plateau and hill region	85	13.3
10	Southern plateau and hill region	63	9.9
11	East coast and plain region	71	11.1
12	Western plain and ghat region	20	3.1
13	Gujarat plains and ghat region	119	18.7
14	Western dry region	27	4.2
Total		638	

Table 2.2.3. Distribution by year of survey.

Year of survey	No. of villages surveyed	Percent	Valid Percent
1984	20	3.1	4.7
1986	10	1.6	2.3
1987	25	3.9	5.9
1988	107	16.8	25.1
1989	140	21.9	32.9
1990	3	.5	.7
1991	121	19.0	28.4
Not Provided	212	33.2	
TOTAL	638	100.0	100.0

Table 2.2.4. Extent of information provided in survey reports.

Information item	No	Yes	Total
Village electrification	209 (32.8)	429 (67.2)	638
Land categories	240 (37.6)	398 (62.4)	638
Energy in agriculture	317 (49.7)	321 (50.3)	638
Animate energy use	366 (57.4)	272 (42.6)	638
Land ownership	139 (21.8)	499 (78.2)	638
Chemical fertilizer use	532 (83.4)	106 (16.6)	638
Crop yields	537 (84.2)	101 (15.8)	638
Seasonal variation in energy	587 (92.0)	50 (7.8)	638
Space heating requirements	592 (92.8)	45 (7.1)	638
Water heating requirements	506 (79.3)	131(20.5)	638
Prices of commodities	604 (94.7)	34 (5.3)	638

As far as energy consumption for end-uses other than for cooking in the domestic sector is concerned, Table 2.2.4 reveals that very few reports provide details of the energy use for water heating (20%) and space heating (7%). Seasonal variation in the energy use is provided in barely 8% for the villages surveyed. The assumptions made in data compilation are given Annexure 2.3.

CHAPTER 3

Survey results

3.1 General features of villages

An average surveyed village is inhabited by less than 1500 inhabitants has about 250 households and is, on an average, 3.7 km from the main road (range of 0-30 km). The average distance from primary health centres was about 5 7 km (the range of distance is 0-65 km).

Table 3.1.1. General features of the villages covered by surveys

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Population	1435 4	1881 5	11	22000	637
Number of households	248 9	330 5	3	4072	638
Distance from the main road (km)	3 7	4 9	0	30	492
Distance for the PHC (km	5 7	9 0	0	65	256
Number of surveyed households	95 3	93 1	3	836	413
Fraction of households surveyed	0 6	0 3	0 03	1	413

Infrastructure in the surveyed villages

Drinking water facilities exist in most villages However there is no information provided in this respect for at least 289 villages As indicated in Table 3.1 2, the average number of wells is about 14 the range of the number of wells is 0-720) and the number of handpumps range from 0 to 500 with the average of 7 handpumps per village

Table 3.1.2. Infrastructure in the surveyed villages

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Total number of schools	1.5	1.4	0	17	495
Number of wells	14.4	58.3	0	702	349
Number of handpumps	7.2	35.6	0	500	262
Number of electrified households	77.8	176.5	0	2600	522
Fraction of households electrified	0.3	0.3	0	1	522

Of the total 638 villages considered for the present study, 429 villages (67.2%) were electrified with the remaining 209 being unelectrified (see Table 2.2.4). Among the villages electrified, however, the number of households with electrical connection varies significantly (from 4 to over 2600 households) with a mean of about 80. A more useful parameter to study is the percentage of total households electrified within an electrified village. As indicated in Table 3.1.2, on an average 30% of the households in electrified villages have electrical connection. There is, however, a large degree of variability (standard deviation of 30%).

Of the 638 surveyed villages, 118 village reports do not provide information about schools in the village. Of the villages for which information is provided, most of the villages have some form of schooling facilities (Table 3.1.3).

Table 3.1.3. Type of highest school in the surveyed villages.

School Type	Number	Percent
None	39	6.2
High	74	11.6
Middle	98	15.4
Primary	309	48.4
Information missing	118	18.5
TOTAL	638	100 0

Note The table presents the type of the highest school The total number of schools, however will be higher. For example, a village with middle school usually also has a primary school while a village with a high school will have both, a middle and a primary school

Land related details

Among the surveyed villages and average village has a total area (Table 3.1 4) of about 935 ha with the range of 5 to over 42000 ha among the surveyed villages) On an average, about 40% of the 535 ha of the agricultural land is irrigated but there is a large variation (standard deviation of 40%). Surprisingly, 143 of the village reports contained no information regarding the total land demarcated in the village, 100 did not give the amount of agricultural land and 231 provided no information regarding the irrigated land Over 30% of the households in the surveyed village were landless and the average per capita agricultural land was 0.5 ha while the total land availability averaged 0 9 ha (Table 3 1 4).

Table 3.1.4. Land details of the surveyed villages

Variable	Mean	Standard deviation	Minimum	Maximum	Number o observatio
Total area (ha)	935 5	2128 1	5	42383 00	495
Agricultural land (ha)	535 9	760 0	0	7869 00	538
Number of households owning land	151 8	214 0	0	2441 00	523
Number of landless households	70 2	132 8	0	1631 00	518
Total irrigated area (ha)	226 4	473 4	0	4638 00	413
Per capita land area (ha)	0 9	1 7	0 02	18 36	495
Per capita agricultural land (ha)	0 5	0 7	0 00	9 91	538
Per capita miscellaneous land* (ha	0 5	1 5	0 00	17 13	470
Fraction landless households	0 3	0 2	0	1	518
Fraction of households owning land	0 7	0 3	0	1	523
Fraction of agri land irrigated	0 4	0 4	0	1	407

* Miscellaneous land, as defined here, is all land other than agricultural land

Asset ownership

The average cattle per village among the surveyed villages (Table 3 1 5) is little over 585 (range 0 to 5900) of which about 405 (range· 0 to 4400) are classified as adults[1]. The details of the population of goats, sheep and othe cattle is depicted in also provided in Table 3.1 5

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[1] This information is likely to be misleading as many of the survey reports do contain information on the break-up of cattle on age criteria The pitfall of the of this data is evident from the range of the all cattle and that of adults

Table 3.1.5. Asset ownership in the surveyed villages

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Number of main cattle	586.5	685.8	0	5900.0	597
Number of cattle (adults)	404.6	512.5	0	4400.0	374
Number of goat and sheep	353.9	970.5	0	15165.0	420
Number of other cattle	38.6	140.6	0	1463.0	178
Per capita cattle population	0.6	0.6	0	9.3	596

Of the devices using commercial forms of energy, electric pump sets are the most common (Table 3.1.6) and this is followed by threshers, diesel pumpsets and tractors. The average numbers, however, can be misleading as the standard deviations presented in Table 3.1.6 would indicate. Information on the presence of electric pumpsets is more common (there is data for 416 of the 638 villages) than that for the diesel pumpsets (372 of the 638 village surveys have information on diesel pumpsets). The details of tractors, threshers, capacity if primemovers in 184 villages along with diesel and electricity consumption in the agro-industries (wherever available) is listed in Table 3.1.6.

Table 3.1.6. Ownership of mechanical devices in the surveyed villages

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Number of electric pumpsets	20.3	52.6	0	530	416
Number of diesel pumpsets	8.1	17.7	0	154	372
Number of tractors	7.1	38.3	0	667	358
Number of threshers	10.3	44.8	0	667	257
Number of agro-industry	1.4	2.0	0	24	385
Agroindustry primemover capacity (kW)	4.8	4.7	0	23	184
Electricity consumption per unit (kWh/d)	13.2	30.5	0	256	261
Diesel consumption per unit (l/d)	1.0	2.4	0	17	162

3.2 Domestic energy consumption

In the surveyed villages, biofuels constitute the main fuels. There are statistically significant variation in the use of biofuels (particularly, firewood) between the agroclimatic zones and these are discussed subsequently along the correlation of biofuel use with other parameters. We begin, however, with the biofuel use aggregated over all the surveyed villages.

Among the biofuels, the use of firewood is predominant (though 161 of 638 villages report no firewood use) and there is a significant variation in the per capita consumption -- the mean per capita (pc) consumption for cooking is 1.2 kg/pc/d and the standard deviation is 1.5 kg/pc/d (Table 3.2.1). The consumption of dungcake is lower -- the average per capita consumption is 0.4 kg/d with a standard deviation of 0.9 kg/d and 203 villages report no dungcake usage. The mean agricultural residue consumption for cooking shows is marginally higher (0.5 kg/d per capita with a high standard deviation of 1.6 kg/pc/d), with 244 of the 638 villages reporting no use at all. Kerosene consumption for cooking is not common (314 of 638 villages reporting no use), very low and, as the standard deviation indicates, the variation in consumption (wherever used) is very high.

For lighting, however, kerosene is the predominant source. Of the 638 villages, 554 use this commercial fuel for lighting The consumption, however, is low (125 ml/hh/d) and the variation (reflected by the standard deviation of 117 ml/hh/d) in the reported use is also high. Variation in the consumption of electricity for lighting (reflected by the standard deviation of 0.71 kWh/hh/d) for the mean of 0.48 kWh/hh/d, however, is higher and fewer villages (462 of the 638) rely on this source for lighting. In at least 378 of the 638 villages (that is almost 60%) both the fuels are used for lighting (Figure 3.5 and 3.6).

Table 3.2.1. Energy use in the domestic sector in the surveyed villages

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Firewood used for cooking (kg/pc/d)	1.2	1.5	0	15	559
Dungcake used for cooking (kg/pc/d)	0.4	0.9	0	14	435
Agri residues used for cooking (kg/pc/d)	0.5	1.6	0	23	394
Kerosene used for cooking (ml/pc/d)	22.0	71.0	0	0	326
Kerosene used for lighting (l/hh/d)	0.1	0.1	0	1	554
Electricity used for lighting (kWh/hh/d)	0.5	0.7	0	8	462

The prices of energy sources are not commonly provided in the survey reports and this is more true for biofuels For example, the fuelwood prices are provided for 92 of the 638 villages while kerosene prices are listed for 199 villages (Table 3 2.2). Though the prices listed are not comparable due to the different years of survey, firewood prices are the highest among the biofuels followed by dungcakes and agricultural residues (Table 3 2.2)

Table 3.2.2. Prices of energy resources in the surveyed villages.

Variable	Mean	Standard deviation	Number of observations
Price of firewood (Rs/kg)	0.5	0 3	92
Price of dungcakes (Rs/kg)	0.3	0.1	50
Price of agri residues (Rs/kg)	0.1	0.1	30
Price of kerosene (Rs/l)	3.2	1.4	199
Price of diesel (Rs/l)	3.9	0.5	90

Variation in fuel consumption

In this section we attempt to describe some of the variation revealed from the data analyzed. We begin first with the biofuel variation *within* different agroclimatic zones[2] and an attempt is made to uncover some of correlation(s) of the observed variation Subsequently, the variation *between* agroclimatic regions are described and the statistical significance of the variation is tested through the analysis of the variance.

The distribution of the biofuel consumption for cooking for the different agroclimatic regions is depicted in Figures 3 7 to 3 13. These charts permit the estimation of the cumulative percentage of households for a specified range of consumption. As an example, Table 3 2 3 summarises the range of fuelwood consumption with the largest proportion of households

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The analysis presented is only for agroclimatic zones 6, 7 8, 9 10 11, an 13 due to the small number of village surveys in the other agroclimatic zones (see Table 3 2 for the break-up of villages according to the agroclimatic regions) In the analysis of the variance data from all the agroclimatic regions are used

Table 3.2.3. Range of consumption of firewood.

Agroclimatic region	Range kg/pc/d·	Percentage of village
6 Trans-gangetic plains	0.25-1.00	89.1
7 Eastern plateau and hill region	diffuse	
8 Central plateau and hill region	0.25-1.00	73.2
9 Western plateau and hill region	**0.75-1.50**	90.6
10 Southern plateau and hill region	0.25-1.00	77.4
11 East coast and plain region	0.25-1.00	58.1
13 Gujarat plains and ghat region	**0.50-1.25**	78.3
Average of all zones	0.25-1 00	62.4

As is indicated in the table and is obvious from the figures, the distribution of villages on the basis of the biofuel consumption is different. The distribution in three agroclimatic regions stand out In agroclimatic zone 7 (Eastern plateau and hills) the distribution is uniform unlike the other agroclimatic regions where the distribution. though skewed. has a perceptible shape The Western Plateau and Hills. on the other hand. have a distribution clustered around the significantly higher per capita fuelwood consumption range of 0 75-1.5 kg/d. Similarly, in Gujarat Plain and Hills region the fuelwood consumption is noticeably higher (though lower than Western Plateau and Hills) with the per capita daily consumption clustered in the range of 0.5-1.0 kg.

Intuitively, there are likely to be some demographic and/or other variables which are likely to have an impact on not only the energy consumption but other factors such as the land-use pattern etc. of interest while formulating energy intervention strategies The statistically significant relationship, in cases where the functional dependence is linear, can be uncovered by computing the correlation coefficients[3] of variables

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[3] The correlation coefficient is only a summary index of the observed strength of association It is often desirable to test the significance of the correlation coefficient of the sample to deduce the population correlation coefficient With the standard assumption of normally

Energy consumption between agroclimatic regions

The sample mean for a group provides the single best estimate for the population value. The confidence interval for the population value can be computed through the sample mean and denotes the probability of the repeated samples (selected under similar conditions) being within the interval. Variations within the sample means (such as per capita firewood consumption for cooking) of different groups (such as agroclimatic zones) may be due to chance or there maybe actual variations within the group means. The common statistical procedure used to test the hypothesis that the group sample means vary due to true differences within the groups is the analysis of variance (ANOVA). Like most other statistical procedures available, ANOVA assumes independently selected samples from normal distribution with the same variance

In ANOVA, the observed variability is separated into the variability of the of the observations about the group mean and the variability of the group means. If the observed variability *within* the group is not high but there is significant variations *between* the group means, there is reason to suspect that the groups are different. For example, if the observed firewood used for cooking within Central Plateau and Hills agroclimatic region does not vary as much as the variation between Central Plateau and Hills and the Upper Gangetic Plains, there are reasons to suppose that the two regions are different in so far as firewood used for cooking is concerned.

Variation in the *firewood used for cooking (kg/pc/d)* has the highest degree of statistical significance (F ratio = 23 68, F probability = < 10^{-4}) The variation is widespread among agroclimatic regions with significant variation among almost all agroclimatic zones (see Table 3.2.5)

Dungcake used for cooking (kg/pc/d) has fairly significant (F ratio = 3 28; F probability = 0.0001) variation among the agroclimatic zones The variation between agroclimatic zones 7 (Eastern Plateau), 6 (Trans-gangetic Plains), 8 (Central Plateau), and 11 (Eastern Coast and Plains) is significant, as is obvious from Table 3 2 6 Variation between 9 (Western

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distributed independent random sample the hypothesis is usually tested using the Student's t distribution and either one- or two-tailed tests can be carried out, though if nothing is *apriori* known the results of the two-tailed test is appropriate The tables listing the correlation coefficient therefore list the results of both the tests

Plateau) and 11 (Eastern Coast and Plains) is significant as is the variation between 11 (Eastern Coast and Plains) and 13 (Gujarat Plains) There is inconclusive variation between agroclimatic zones as far as *agricultural residues used for cooking* is concerned (F ratio = 1 61; F probability = 0.86) and the means and other relevant statistics are presented in Table 3.2 7.

The noticeable significance (F ratio = 2.99, F probability = 0.0008) in the variation of *kerosene used for cooking* (l/pc/d) is due to the high reported use in the agroclimatic zone 10, that is Southern Plateau, (see Table 3 2.8). The variation between the other agroclimatic zones is not statistically significant.

There are noticeable variation between the agroclimatic regions in the energy use for lighting The variation between agroclimatic zones in the *kerosene used for lighting* (l hh d) is very significant (F ratio = 13.11; F probability = < 10^{-4}) with the kerosene use showing statistically significant variation among almost all agroclimatic zones (Table 3 2.9). Variation in the *electricity used for lighting* Table 3 2 10) has similar statistical significance (F ratio = 10.06, F probability = < 10^{-4}) though the variation is not widespread among the agroclimatic zones -- zones 4 (Middle Gangetic Plains) and 6 (Trans-gangetic Plains), with high level of consumption account for large part of the variation

Table 3.2.5. Firewood used for cooking (kg/pc d)

Group	Count	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		
Grp 1	5	1.1	0.8	0.4	< 0.1	To	2.1
Grp 2	15	1.9	1.1	0.3	1.3	To	2.5
Grp 3	6	1.0	0.5	0.2	0.4	To	1.5
Grp 4	31	0.4	0.3	0.1	0.3	To	0.6
Grp 5	1	0.3					
Grp 6	64	0.3	0.3	< 0.1	0.3	To	0.5
Grp 7	65	3.3	2.3	0.3	2.8	To	4.0
Grp 8	41	1.0	0.9	0.1	0.7	To	1.2
Grp 9	85	1.0	0.4	< 0.1	0.8	To	1.0
Grp10	53	1.0	0.7	0.1	0.8	To	1.1
Grp11	62	1.8	2.0	0.3	1.2	To	2.3
Grp12	19	1.0	0.5	0.1	0.7	To	1.2
Grp13	86	0.8	0.5	< 0.1	0.8	To	1.0
Grp14	26	0.5	0.5	0.1	0.4	To	0.5
Total	559	1.2	1.5	0.1	1.1	To	1.3

Table 3.2.6. Dungcake used for cooking (kg pc/d)

Group	Count	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		
Grp 1	3	0.2	0.2	0.1	< 0.1	To	0.6
Grp 2	15	0.2	0.3	0.1	< 0.1	To	0.4
Grp 3	7	0.6	0.3	0.1	0.3	To	0.8
Grp 4	31	0.4	0.2	< 0.1	0.3	To	0.5
Grp 5	1	1.3					
Grp 6	65	0.6	0.3	< 0.1	0.5	To	0.7
Grp 7	31	< 0.1	< 0.1	< 0.1	< 0.1	To	< 0.1
Grp 8	41	0.6	0.7	0.1	0.4	To	0.9
Grp 9	83	0.2	0.1	< 0.1	0.1	To	0.2
Grp10	20	0.2	0.3	< 0.1	0.1	To	0.4
Grp11	44	0.9	2.4	0.4	0.1	To	1.6
Grp12	13	0.1	0.2	0.1	< 0.1	To	0.3
Grp13	54	0.2	0.3	< 0.1	0.1	To	0.3
Grp14	27	0.6	0.4	0.1	0.5	To	0.8
Total	435	0.4	0.9	< 0.1	0.3	To	0.5

Table 3.2.7. Agricultural residues used for cooking (kg/pc/d)

Group	Count	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		
Grp 2	15	0.4	0.3	0.8	0.2	To	0.5
Grp 3	5	0.6	0.3	0.1	0.2	To	1.0
Grp 4	31	0.3	0.2	< 0.1	0.2	To	0.4
Grp 5	1	< 0.1					
Grp 6	61	0.3	0.3	< 0.1	0.3	To	0.4
Grp 7	31	0.2	0.7	0.1	< 0.1	To	0.5
Grp 8	33	0.3	0.3	0.1	0.1	To	0.4
Grp 9	82	0.5	0.3	< 0.1	0.4	To	0.6
Grp10	11	0.8	1.1	0.3	0.1	To	1.6
Grp11	48	1.3	4.4	0.6	0.1	To	2.6
Grp12	12	0.1	0.2	0.1	< 0.1	To	0.2
Grp13	42	0.3	0.3	0.1	0.2	To	0.4
Grp14	22	0.1	0.2	0.1	< 0.1	To	0.2
Total	394	0.5	1.6	0.1	0.3	To	0.6

Table 3.2.8. Kerosene used for cooking (l/pc d)

Group	Count	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		
Grp 1	3	0733	0058	0033	0590	To	0877
Grp 2	15	.0018	0020	0005	0007	To	0029
Grp 4	28	0104	0114	0022	0060	To	0148
Grp 6	58	0152	0145	0019	0114	To	0190
Grp 7	1	0000					
Grp 8	33	0348	1734	0302	negl	To	0962
Grp 9	65	.0111	0148	0018	0075	To	0148
Grp10	26	0767	1015	0199	0356	To	1177
Grp11	13	0038	0065	0018	negl	To	0077
Grp12	15	0663	1131	0292	0036	To	1289
Grp13	48	0229	0319	0046	0136	To	0321
Grp14	21	0003	0007	0001	0000	To	0006
Total	326	0228	0709	0039	0151	To	0305

Table 3.2.9. Kerosene used for lighting (l/hh.d

Group	Count	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		
Grp 1	3	0033	0035	0020	- 0054	To	0121
Grp 2	15	2270	.0454	0117	2018	To	2522
Grp 3	7	.2119	0466	0176	1688	To	2549
Grp 4	31	2965	1641	0295	2364	To	3567
Grp 5	1	1030					
Grp 6	61	.0556	0850	0109	0338	To	0774
Grp 7	65	1770	2220	0275	1220	To	2320
Grp 8	41	1040	0482	0075	0888	To	1192
Grp 9	85	0951	0271	0029	0892	To	1009
Grp10	51	0926	0956	0134	0657	To	1195
Grp11	64	1233	0511	0064	1105	To	1361
Grp12	19	1084	0385	0088	0899	To	1270
Grp13	84	1254	0730	0080	1096	To	1413
Grp14	27	0964	0457	0088	0783	To	1145
Total	554	1250	1168	0050	1152	To	1347

Table 3.2.10. Electricity used for lighting (kWh/hh/d)

Group	Count	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		
Grp 1	3	0.2	0.2	0.1		To	0.6
Grp 2	15	< 0.1	< 0.1	< 0.1	< 0.1	To	< 0.1
Grp 3	7	< 0.1	< 0.1	< 0.1		To	0.1
Grp 4	8	1.0	2.0	0.7		To	2.7
Grp 5	65	1.2	0.6	< 0.1	1.1	To	1.4
Grp 6	37	0.3	1.3	0.2		To	0.7
Grp 7	33	0.3	0.6	0.1	0.1	To	0.5
Grp 8	84	0.4	0.3	< 0.1	0.4	To	0.5
Grp 9	49	0.3	0.3	< 0.1	0.2	To	0.4
Grp10	59	0.4	0.6	< 0.1	0.3	To	0.6
Grp11	18	0.2	0.3	< 0.1	0.1	To	0.4
Grp12	59	0.3	0.4	< 0.1	0.2	To	0.4
Grp13	23	0.4	0.6	0.1	0.1	To	0.6
Total	462	0.5	0.7	< 0.1	0.4	To	0.5

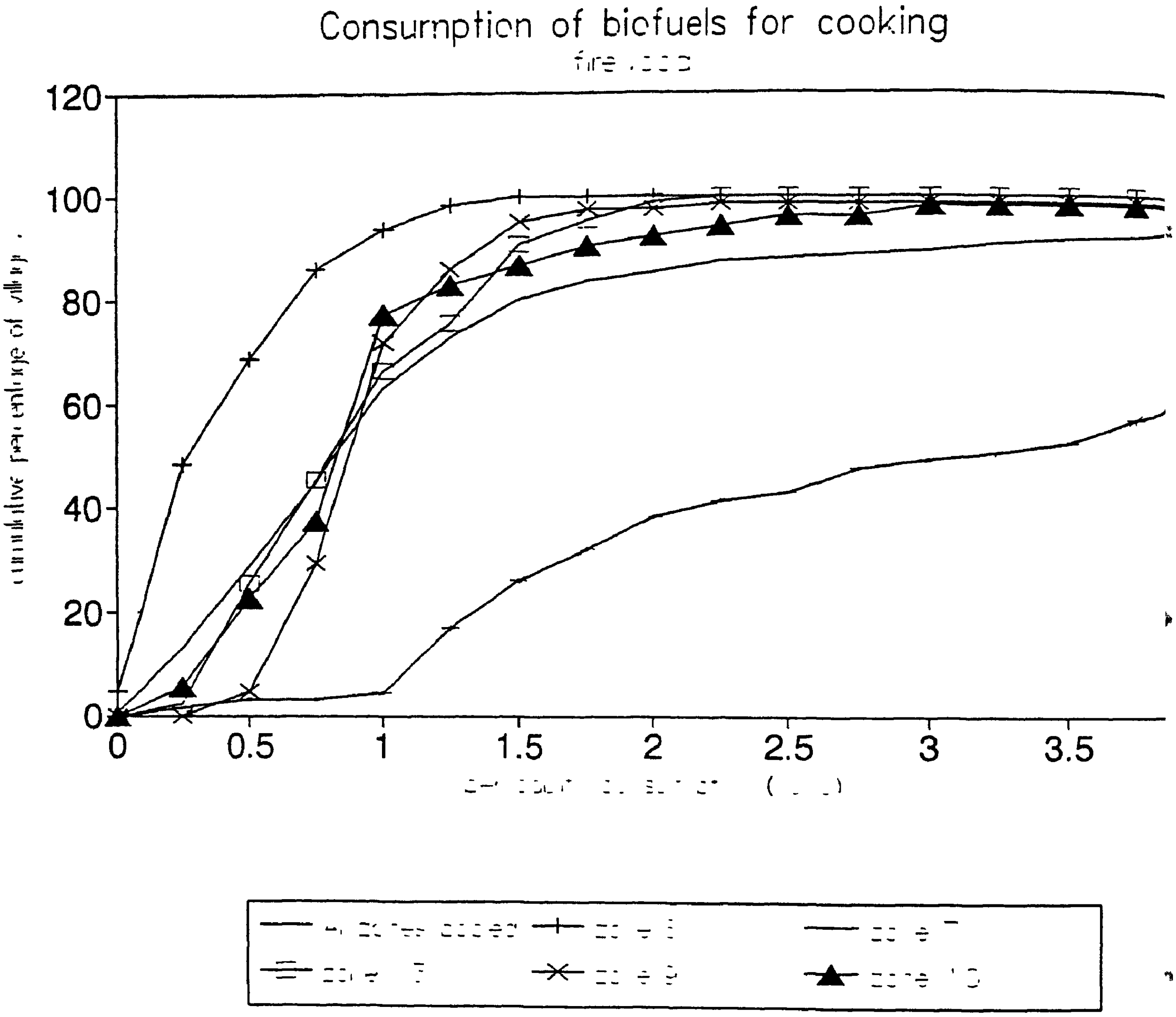

Consumption of biofuels for cooking
fire wood
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
zone 10

Figure 3.1

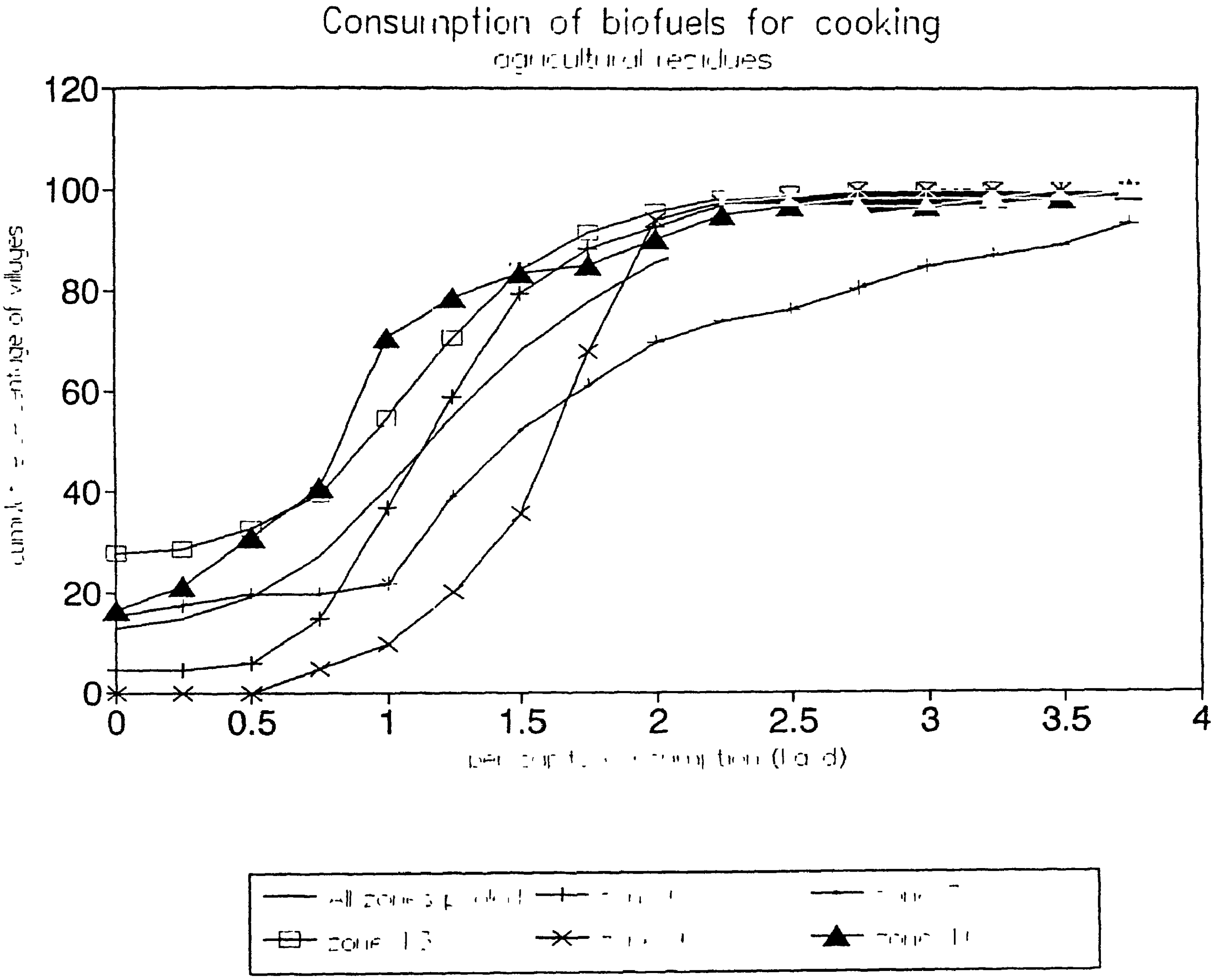

Consumption of biofuels for cooking
agricultural residues
120
100
80
60
40
20
0
cumulative percentage of villages
0
0.5
1
1.5
2
2.5
3
3.5
4
per capita consumption (kg/d)
All zones pooled
zone 13
zone 11

Figure 3.2

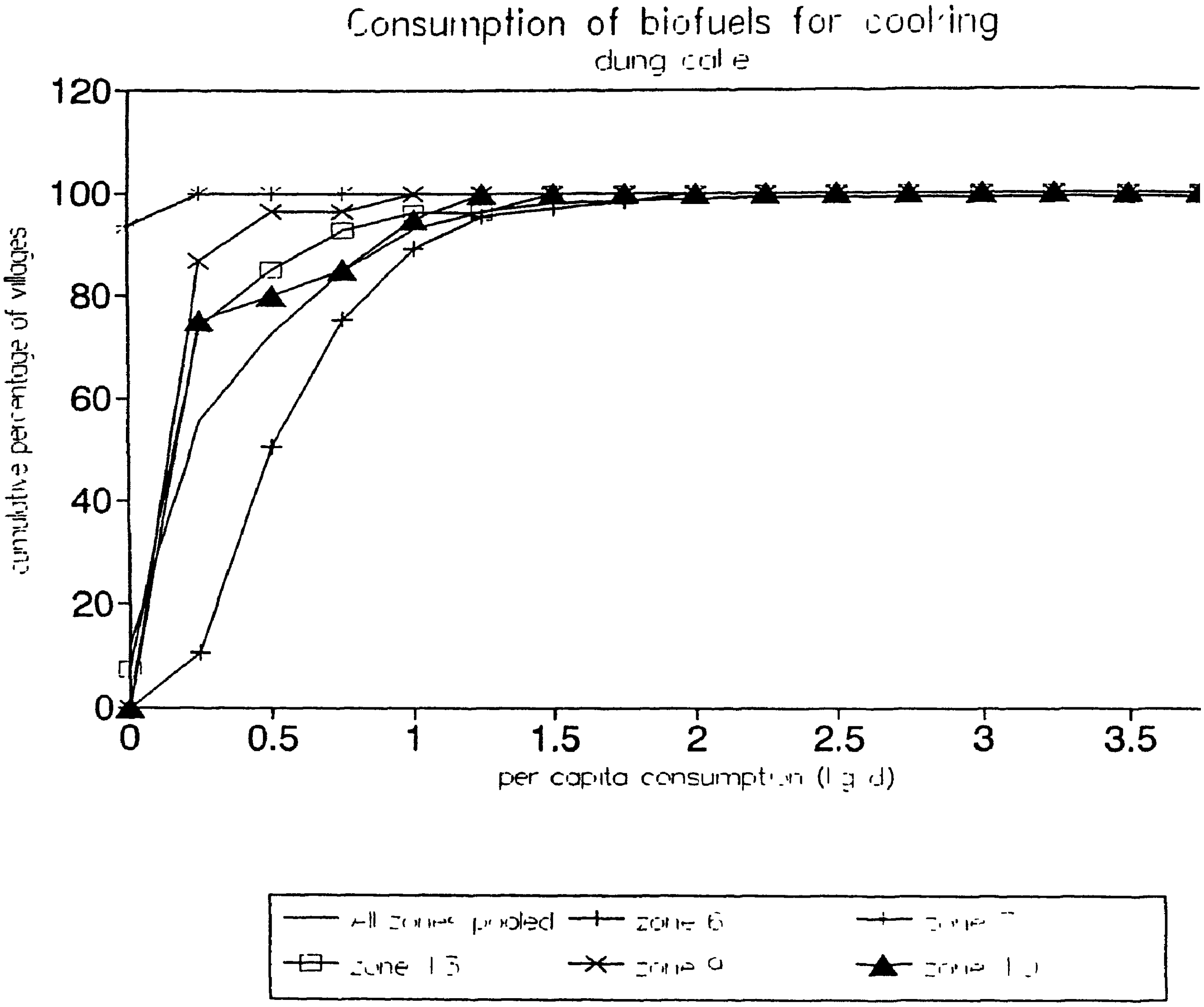

Consumption of biofuels for cooking
dung cake
120
100
80
60
40
20
0
cumulative percentage of villages
0
0.5
1
1.5
2
2.5
3
3.5
per capita consumption (kg/d)
All zones pooled
zone 6
zone 7
zone 13
zone 9
zone 10

Figure 3.3

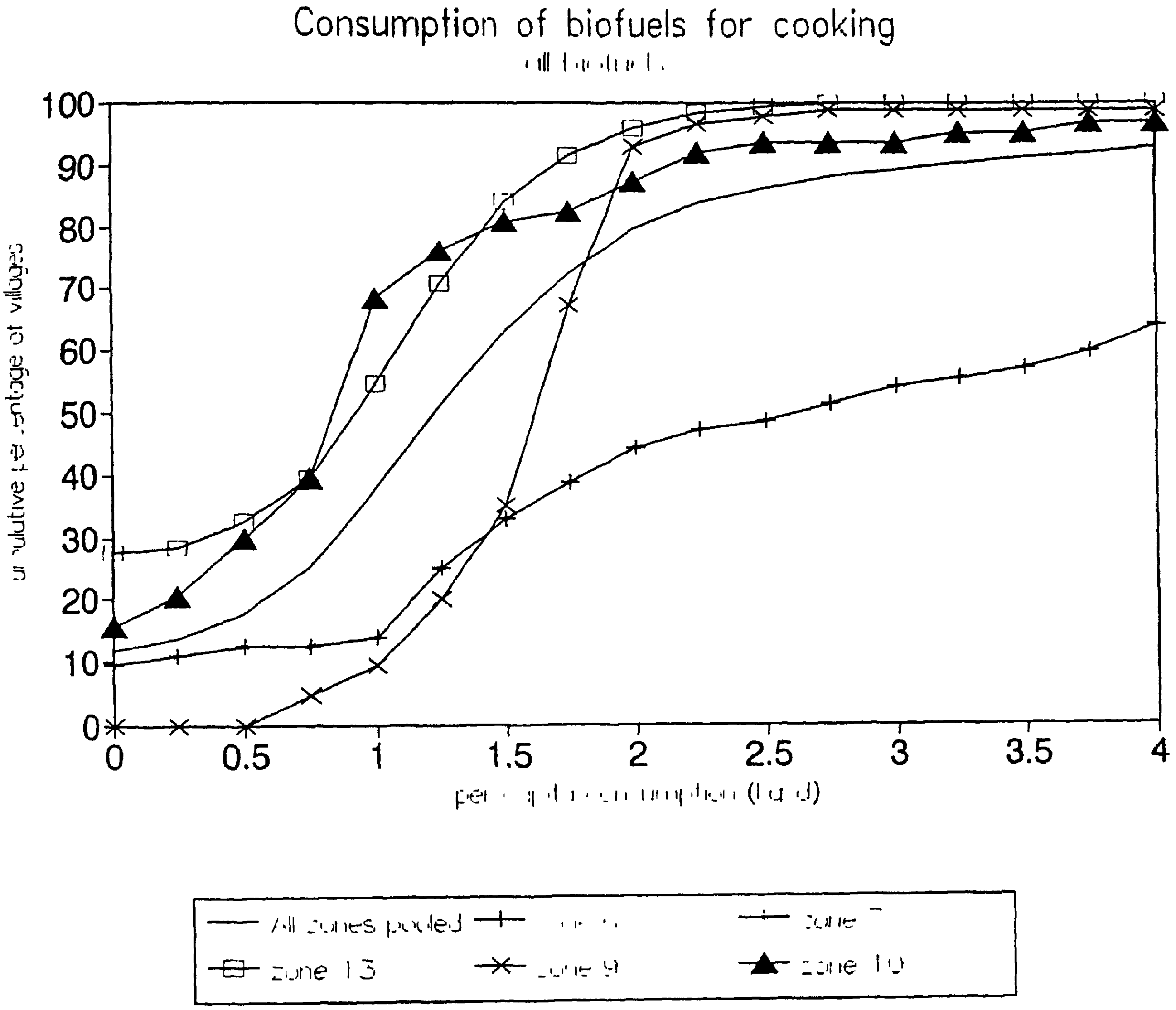

Consumption of biofuels for cooking
all biofuels
100
90
80
70
60
50
40
30
20
10
0
cumulative percentage of villages
0
0.5
1
1.5
2
2.5
3
3.5
4
per capita consumption (kg/d)
All zones pooled
zone 7
zone 13
zone 9
zone 10

Figure 3.4

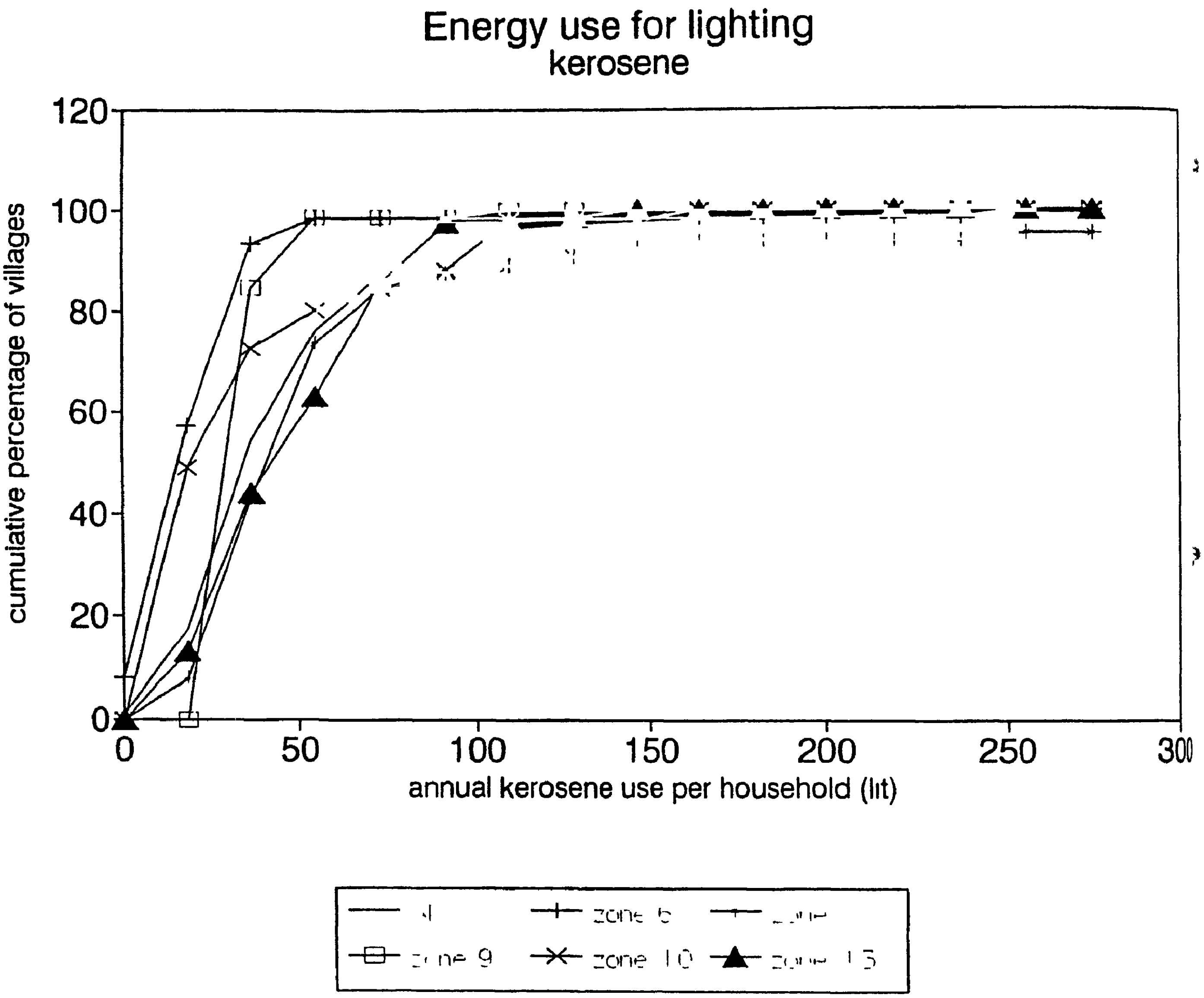
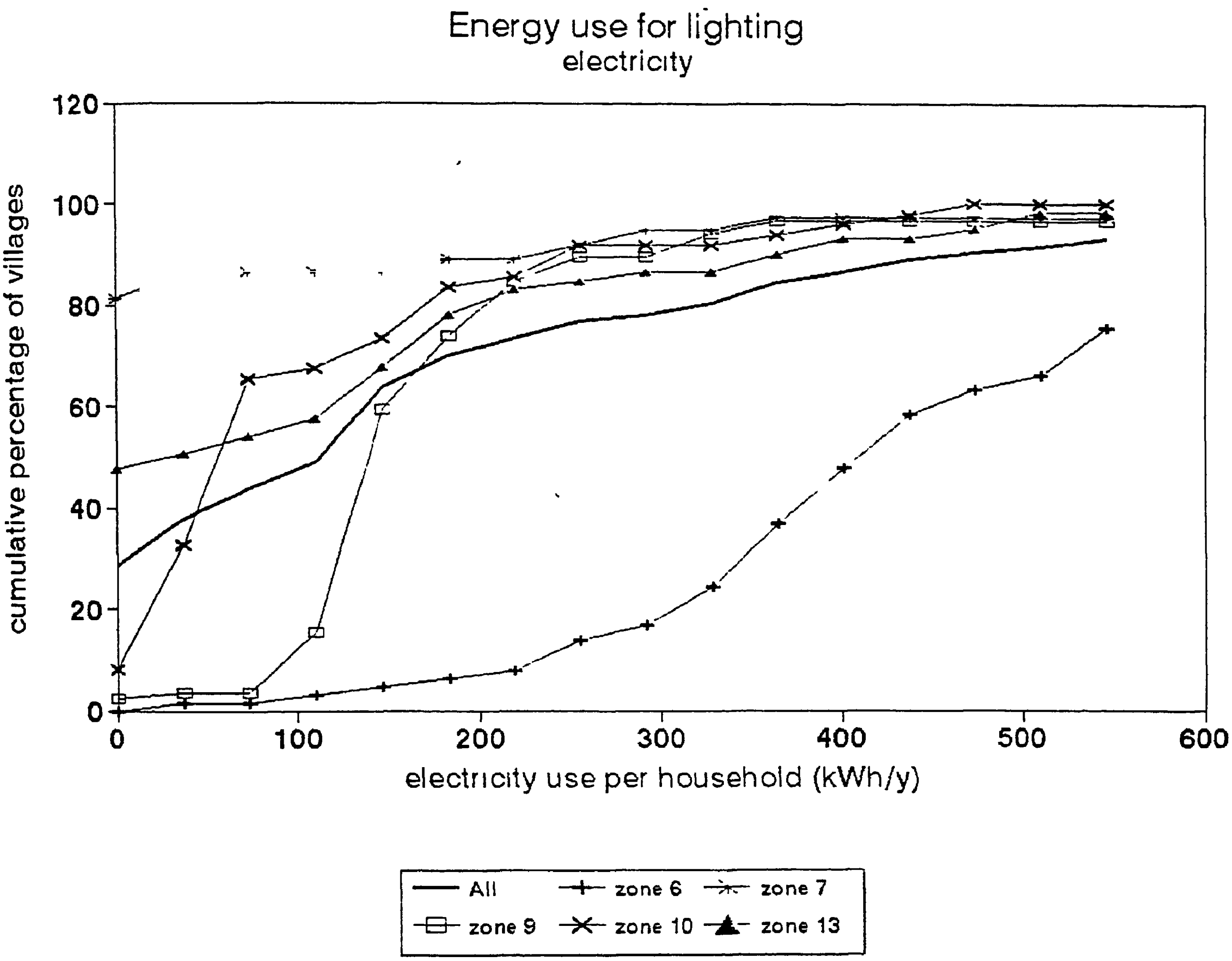

Energy use for lighting
kerosene
120
100
80
60
40
20
0
cumulative percentage of villages
0
50
100
150
200
250
300
annual kerosene use per household (lit)
4
zone 6
zone
zone 9
zone 10
zone 15

Figure 3.5



Energy use for lighting
electricity
cumulative percentage of villages
120
100
80
60
40
20
0
0
100
200
300
400
500
600
electricity use per household (kWh/y)
All
zone 6
zone 7
zone 9
zone 10
zone 13

Figure 3.6

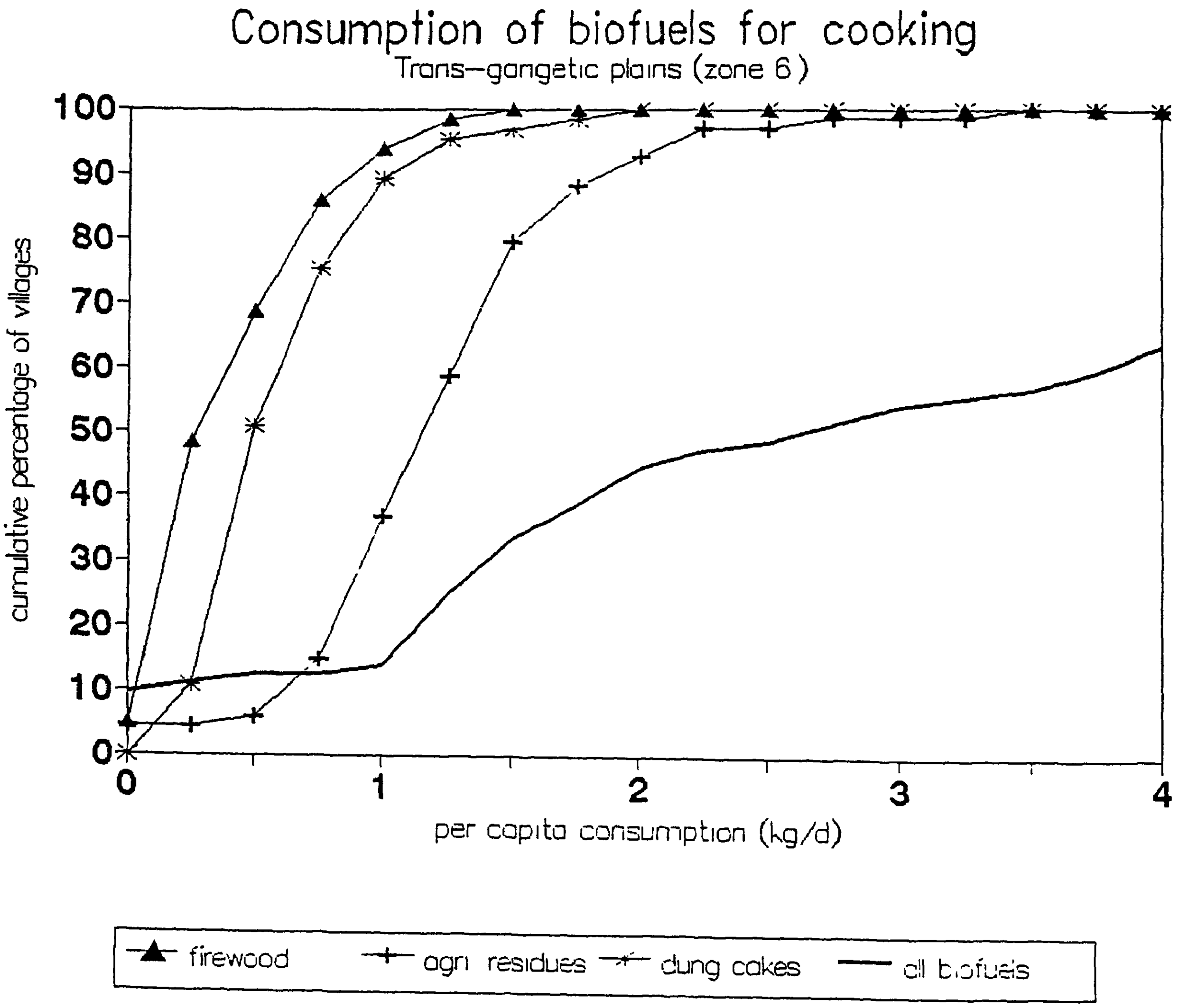

Consumption of biofuels for cooking
Trans-gangetic plains (zone 6)
cumulative percentage of villages
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
per capita consumption (kg/d)
firewood
agri residues
dung cakes
all biofuels

Figure 3.7

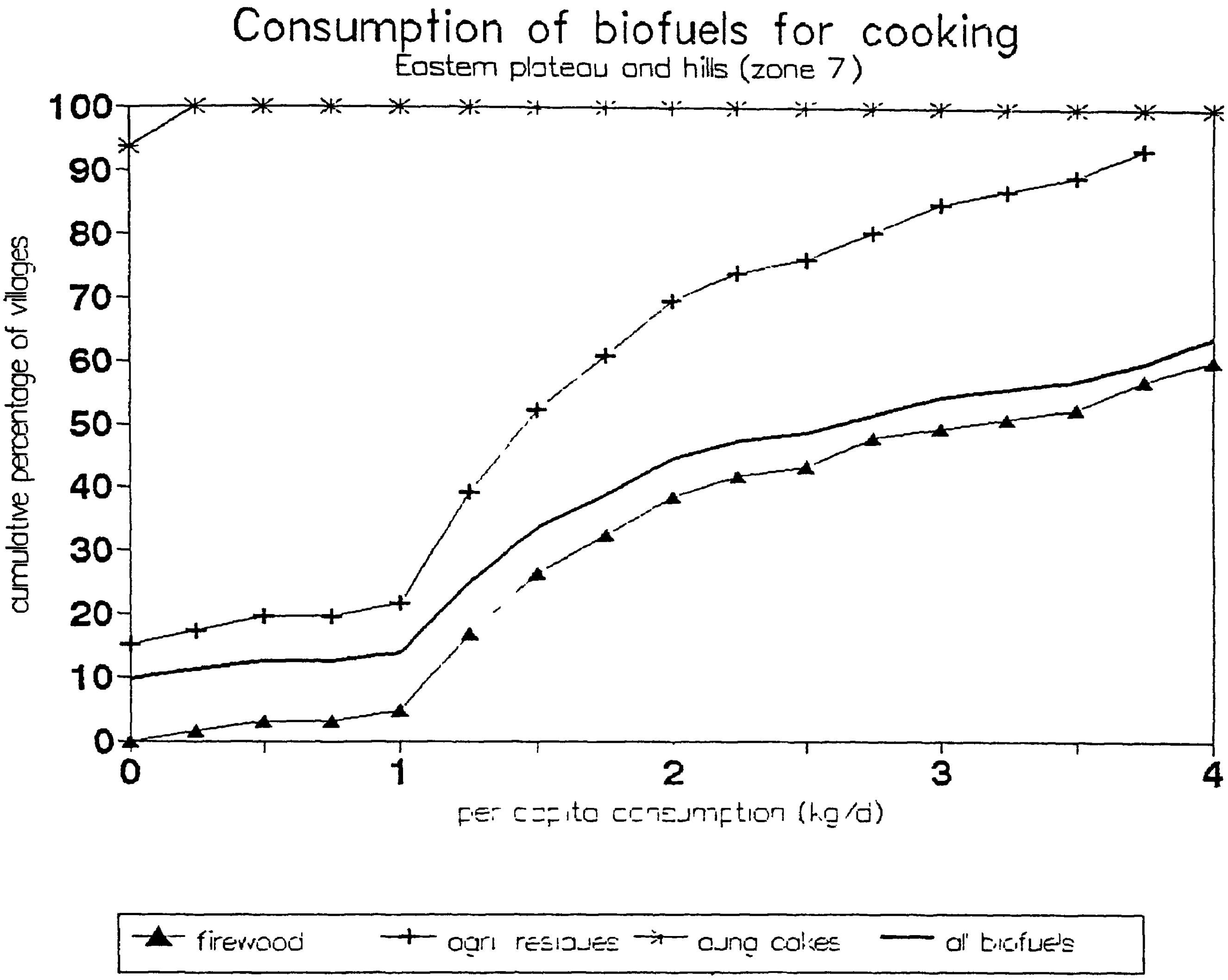

Consumption of biofuels for cooking
Eastern plateau and hills (zone 7)
100
90
80
70
60
50
40
30
20
10
0
cumulative percentage of villages
0
1
2
3
4
per capita consumption (kg/d)
firewood
agri residues
dung cakes
all biofuels

Figure 3.8

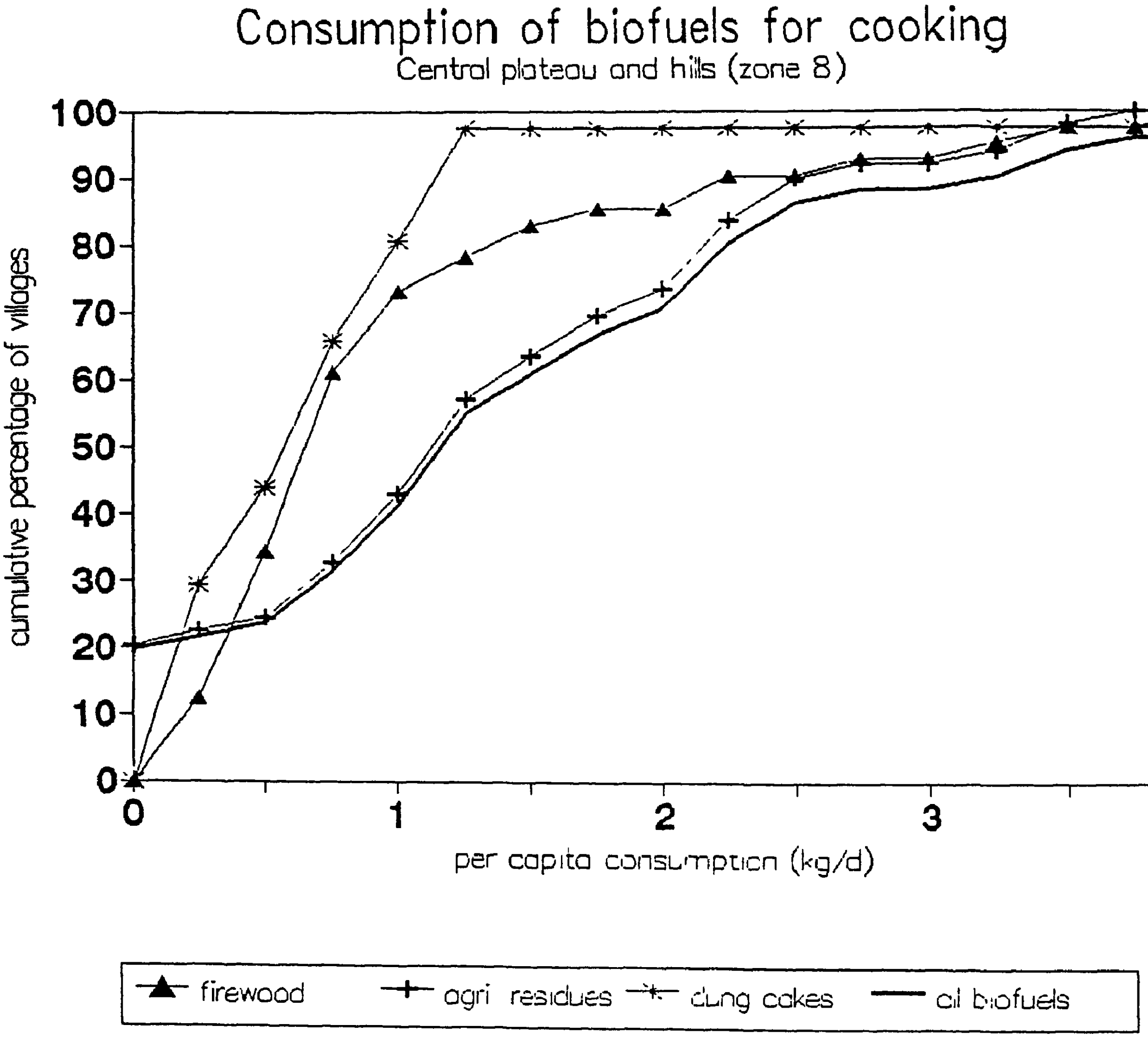

Consumption of biofuels for cooking
Central plateau and hills (zone 8)
cumulative percentage of villages
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
per capita consumption (kg/d)
firewood
agri residues
dung cakes
all biofuels

Figure 3.9

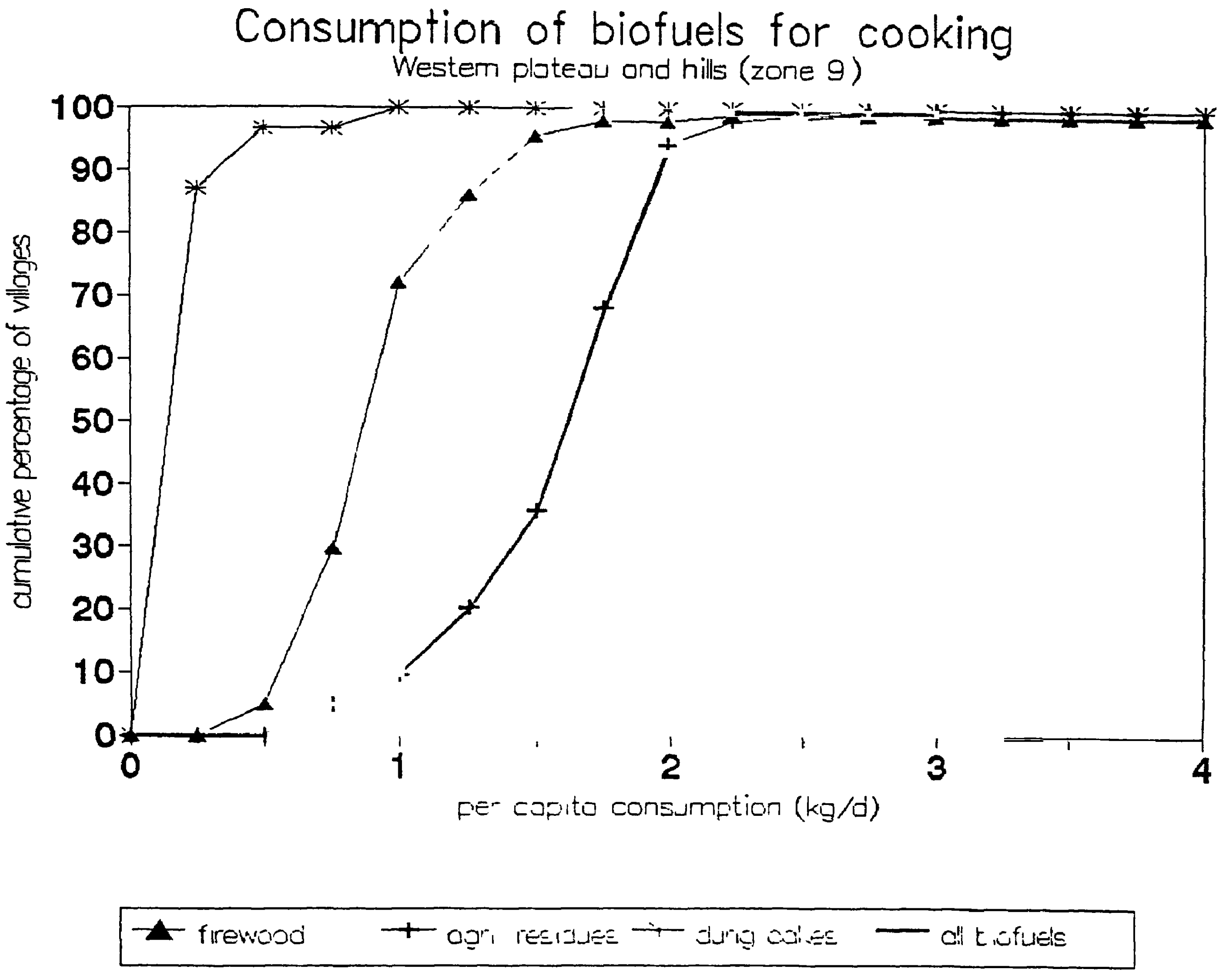

Consumption of biofuels for cooking
Western plateau and hills (zone 9)
100
90
80
70
60
50
40
30
20
10
0
cumulative percentage of villages
0
1
2
3
4
per capita consumption (kg/d)
firewood
agri. residues
dung cakes
all biofuels

Figure 3.10

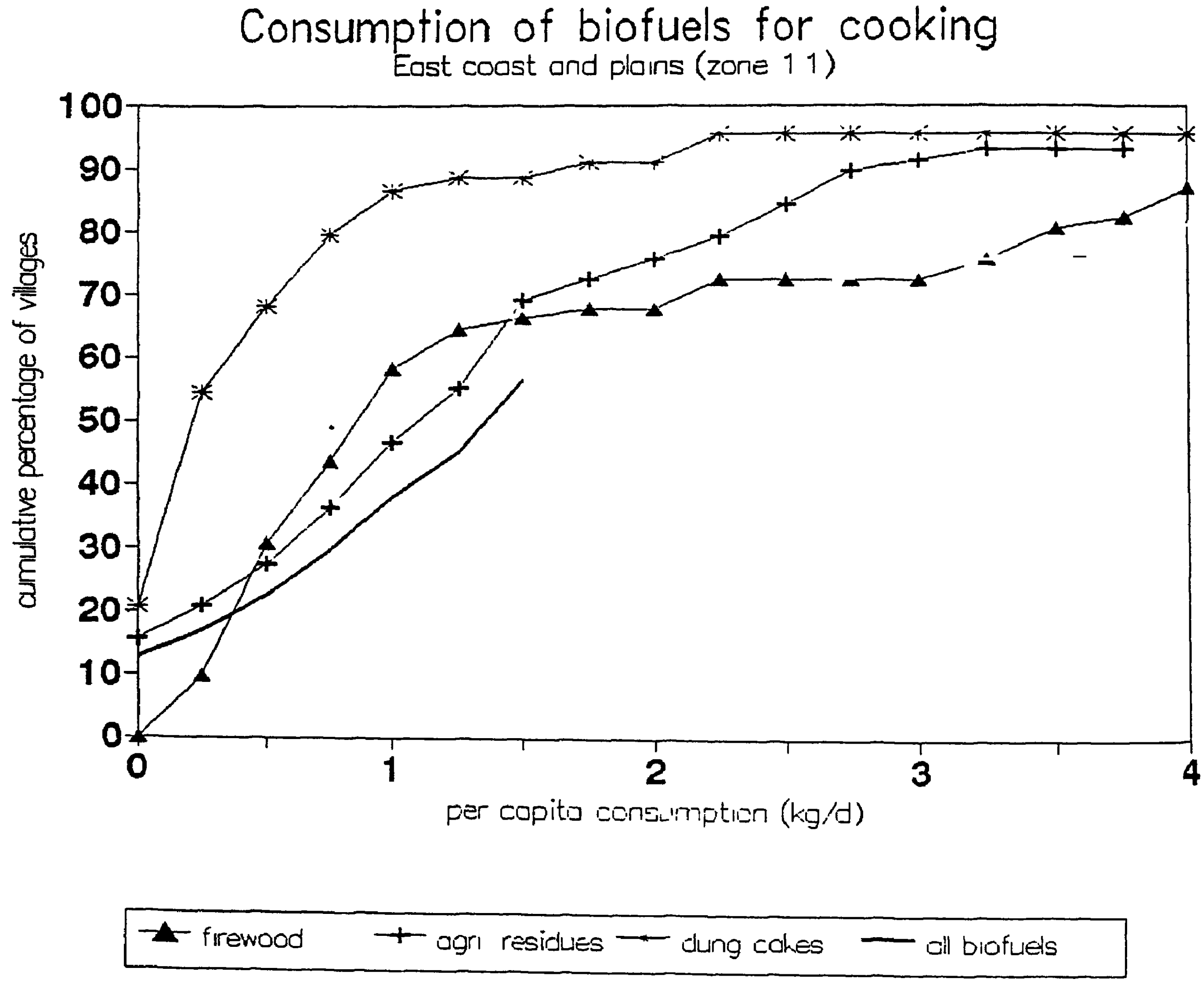

Consumption of biofuels for cooking
East coast and plains (zone 11)
cumulative percentage of villages
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
per capita consumption (kg/d)
firewood
agri residues
dung cakes
all biofuels

Figure 3.11

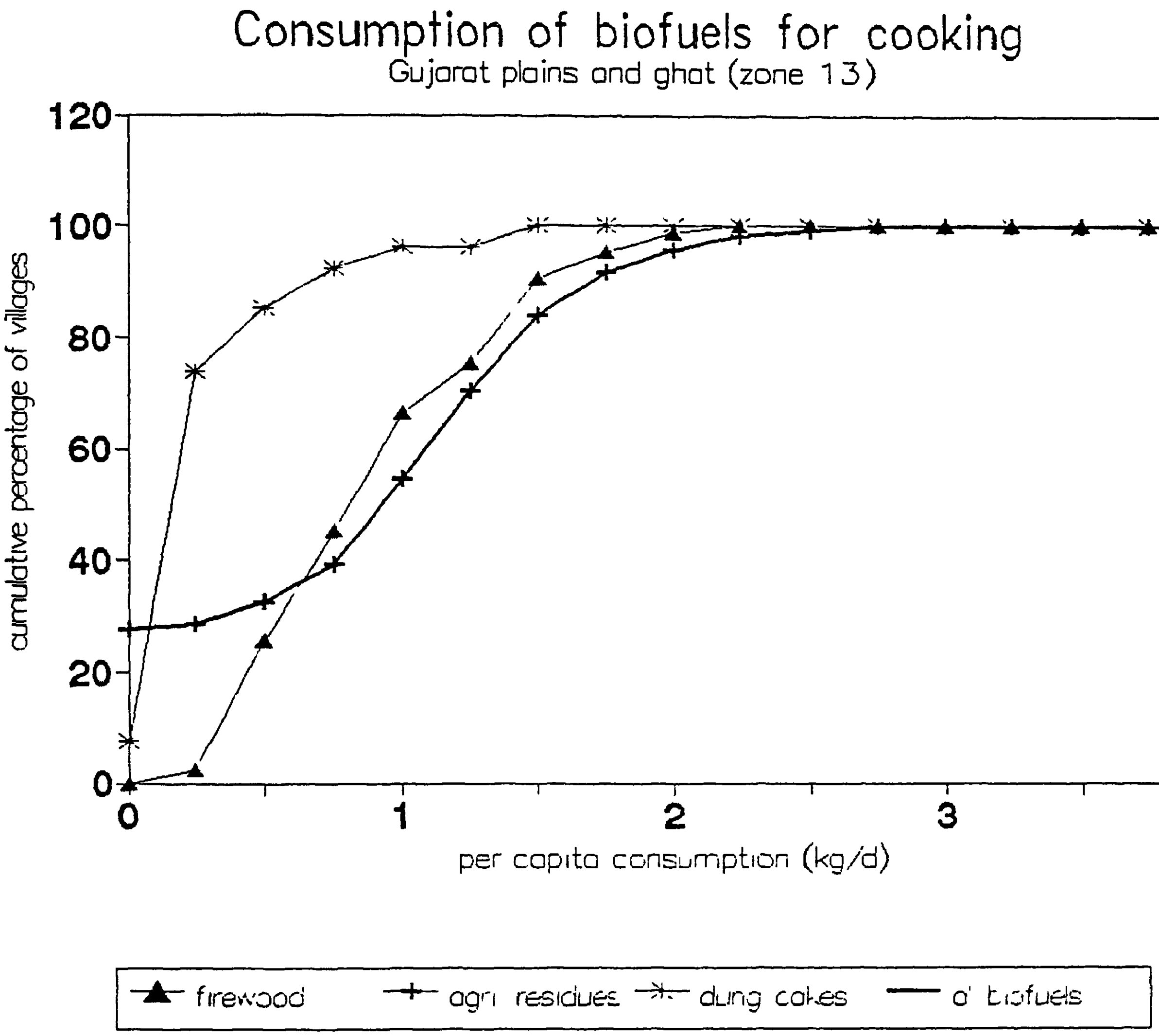

Consumption of biofuels for cooking
Gujarat plains and ghat (zone 13)
120
100
80
60
40
20
0
cumulative percentage of villages
0
1
2
3
4
per capita consumption (kg/d)
firewood
agri residues
dung cakes
all biofuels

Figure 3.12

CHAPTER 4

Estimation of aggregate demand

For an effective policy for the rural energy sector, the magnitude of the demand needs to be quantified and, to the extent possible, these have to be projected over some reasonable planning period. In the absence of an understanding of the factors influencing energy demand, aggregating energy demand in the past has essentially used estimates of per capita energy consumption based on surveys and the population.

This chapter begins with a summary of some of the major attempts in the past to estimate and aggregate energy demand in the rural domestic sector of India. The efforts to formulate domestic rural requirements along with their limitations of these are first discussed Results of some of the efforts for quantifying biofuel consumption based on the results of this study is thereafter presented These are used to estimate the biofuel use in the rural domestic sector and the results are compared with other estimates in the concluding section.

4.1 Estimates of rural energy requirements

Over the last three decades several attempts have been made to estimate energy requirements in India The major efforts are

1 The Energy Survey of India (ESI) Committee (1965),
2 The Fuel Policy Committee (1974),
3 The Working Group on Energy Policy (1979),
4 The Advisory Board on Energy (1985), and
5 The Energy Demand Screening Group Report (1986)

These are, by no means, the only attempts The reason for the importance of these studies lies in the emphasis they placed on energy requirements. In other attempts estimating energy requirement was a part of some larger exercise. For instance, the National Commission on Agriculture (NCA 1976) projected fuelwood requirement till the turn of the century but this was carried out for the purpose of evolving a forest policy The (Rajadhyaksha) Committee on Power (DOP 1980) estimated the requirements of electricity for rural areas for the purpose of power sector planning. Gadgil et al. (1989) make district-wise estimates for biomass requirement in order to develop biomass balance tables. The major interest of these studies was to examine the impact of the energy requirement on their point of interest.

We begin with a discussion of the methodology and the underlying assumptions of the estimates for rural household energy requirement. Logically, discussion of the estimates of the Working Group on Energy Policy (WGEP 1979) would appear adequate. However, a closer examination of the report of the WGEP indicated that several crucial assumptions of the WGEP were linked to the work of the ESI as a result of which the ESI report is first discussed.

The Energy Survey of India (ESI) Committee (1965)

The ESI relied on the survey of the National Council for Applied Economic Research (NCAER) in 1962 of approximately 9000 rural households (ESI 1965) Unfortunately, the fuel-mix was aggregated at the national level and no obvious attempt was made to examine the regional variation of the fuel-mix even though the NCAER survey was based on stratified random sample of households distributed all over India from which it may have been possible to examine this variation. Although the fuel-mix in terms of all fuels was shown to change over time, this was attributed to likely increase of consumption of commercial fuels - both, the total useful energy requirement and the share of biomass fuels *among themselves* are assumed to have the same fraction. The relative fuel-mix among the biofuels were 65:15:20 for fuelwood, dung cake, and agricultural residues, respectively an the per capita daily useful energy requirement was assumed at 510 kcal (2.13 MJ) while the corresponding level for urban areas was 535 kcal (2.24 MJ)

The per capita energy requirement in the domestic sector of both, rural and urban areas was projected to grow Commercial energy sources (mainly, kerosene and electricity) were expected to account for most of this increase In rural areas, agricultural residues were expected to absorb a part of the increase in requirement, the use of which the ESI assumed would grow with the growth in agricultural production (ESI 1965)

Working Group on Energy Policy (1979)

The second major attempt to estimate aggregate sectoral energy requirement was initiated by the Government of India in December, 1977 when it set up the Working Group on Energy Policy (WGEP).

The WGEP made limited use of actual survey data even though it quoted extensively from the results of the 18th and 28th round of the National Sample Survey (NSS). For example, it listed the fuel-mix indicated by the 28th round NSS data but used a fuel-mix which had no apparent links with the NSS data. In choosing the fuel-mix it appears that the WGEP was guided more by the assumptions of the ESI Committee than by the indications of the NSS or other data. The WGEP also assumed the same energy requirements as the ESI -- 510 kcal (2 13 MJ) per capita daily for rural and 535 kcal (2.24 MJ) for urban areas In making all the projections the WGEP used these values and did not account for the difference in the consumption levels among households of different expenditure class indicated by the NSS 28th round data Regional variations in the energy consumption (and fuel mix) were also not taken into account and the projections were made for the country as a whole

Arguing that the long term projection of fuel-mix was essentially a macro-policy decision, the WGEP held the view that an efficient utilisation of energy resources required an attempt to displace non-commercial with commercial fuels (mainly kerosene, soft coke and electricity - in that order) over time for both lighting and cooking With this objective, the WGEP assumed that there would be a gradual shift from the dependence on non-commercial fuels as a result of government policy For example, from the estimated 99% rural households using non-commercial fuels in 1975/76, only 70% were projected to be using non-commercial fuels in 2000 01 with a large fraction of the shift being accounted by kerosene By 2000/01 over 20% of the households were projected to be using kerosene for cooking (WGEP 1979.

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Like the ESI, the ABE had the advantage of having access to a large body of data collected by a national survey conducted by the NCAER in the year 1978/79 Surprisingly, like the ESI, though the ABE discussed the results of the NCAER (and that of several other surveys), the final normative energy requirement recommended by the ABE had little connection with the survey data on actual consumption. Similarly, the fuel-mix were assumed to be constant in all the states - even though the NCAER survey had summarised the fuel-mix at the state level and the ABE had access to the data (unpublished at that time). Furthermore, the fuel mix was assumed to remain constant up to 2004 05 -- the terminal year for the projection. Though empirical evidence is rare, it is commonly believed that fuel mix changes in response to biomass availability/ scarcity. There are, however, evidence of a correlation of the level of a particular biofuel used with the availability of that fuel from which changes in fuel-mix with availability would appear likely.

The LPG consumption in the urban areas were used as a basis for determining the normative (desired) level of thermal energy consumption among rural households. To quote

> a 15 kg LPG cylinder is taken to last for 30 days for a household of five Calorific value of LPG is taken at 10300 kcal kg (43.12 MJ/kg) and appliance efficiency at 60% (ABE 1985 72).

The useful cooking energy requirement for the households thus estimated was 620 kcal (2 60 MJ) per person per day The estimates of LPG consumption were, however, not adequately justified in terms of data One study (TERI 1992) estimated the energy consumed by households with LPG connections to be in the in the range of 225 kcal (940 kJ) to 480 kcal (2 MJ) per person per day for in 1988/89 which is significantly lower than the ABE's estimate

The lighting energy norms were derived from the results of a survey of greater Bombay and were assumed at per capita 30 kcal/d (125 kJ/d). The lighting units chosen by the ABE (kcal) were strange and common terms of illumination engineering were absent in the section dealing with lighting energy requirements The normative useful per capita daily energy requirement for lighting and thermal energy in the rural domestic sector proposed by the ABE was 650 kcal (2 72 MJ).

The Energy Demand Screening Group (1986)

The Energy Demand Screening Group (EDSG) was established for arriving at common requirement estimates for initialising the energy sector model of the inter-sectoral models for perspective planning of the Planning Commission. For the rural domestic sector, the EDSG felt that the ABE's norms were too high. Quoting results of several energy surveys, the EDSG suggested that this norm be adopted for the urban population but for the rural population the average useful heat consumption should be taken as 520 kcal (2.18 MJ) per person per day *in 2004/05* (EDSG 1986).

It may be worthwhile to note that the value of 620 kcal (2.60 MJ) (of ABE) is closer to the survey results quoted by EDSG than 520 kcal (2.18 MJ) per person per day. Presumably, the survey results quoted and the recommended normative energy requirements were to have some relationship. The value, however, appears to have different basis The EDSG used the energy requirements suggested by the ESI and assumed the level of growth in energy requirement over time that the ESI estimated. With these assumptions, the level of requirement predicted for 2004/05 worked out to 520 kcal (2.18 MJ) of useful energy per person per day

Summary of requirement estimates for rural households

Some of the major points regarding the past attempts to estimate the energy requirement and/or energy consumption for the domestic sector are as follows.

☐ All studies, except the ABE, relied on energy consumption levels of the ESI (of 510 kcal or 2.13 MJ per capita daily) Therefore, the different versions of the requirement estimates reflected *nothing apart from changes in population* The ESI, on its part, based the consumption figure of NCAER surveys in between (1958-60).

Though all requirement estimate studies had access to survey data at the state level, they appear to have used national averages of the data. thereafter disaggregating requirement at the state level. Obviously, information regarding the regional variation in requirements is lost in the process and the difference in the requirement is purely due to the difference in population.

☐ The most crucial aspect, in so far as the energy policy and technology options are concerned, is the fuel mix for meeting the energy requirement. None of the studies following the ESI made any serious attempt to examine this issue. There have been no attempts to look at the variation in the mix of biofuels over time and the little effort that has been made in this direction was restricted to what role commercial fuels (kerosene and electricity) can play in changing the proportional contribution of different fuels -- the proportion of the different biofuels has been assumed constant over time in all studies. In many studies (for example, the ABE), the national average of the fuel mix were used to estimate the state-wise requirements of different biofuels. As with the requirement estimates, this led to loss of information regarding the proportional contribution of different biofuels at the state level.

☐ It may be worthwhile to point out that there is, to the best of our knowledge, no empirical evidence that the energy consumption has increased with time In fact the different rounds of NSS data indicate more or less constant consumption levels

☐ All studies to estimate requirement have made assumption that urban household energy consumption are higher than the rural -- starting with the ESI to the EDSG. The difference in the ESI estimates were marginal (the urban requirement was higher by 25 kcal (105 kJ) per capita daily) and were based on the NCAER surveys of 1958-60 The 1978/79 survey of the NCAER (NCAER 1985) supports the earlier findings. Studies in the past (see TERI 1991) indicate that the urban levels of useful domestic energy consumption appear lower or comparable than those indicated by the surveys for rural areas In light of this, it appears difficult to explain the common assumption of higher urban energy consumption

4.2 Energy consumption in the rural domestic sector

The emphasis on the normative nature or the *energy requirements*, rather than *energy consumption* levels needs in all of the macro level estimates needs to be noted In contrast, substantial efforts to estimate energy consumption has been largely ignored in the macro planning exercises of the past though, ironically, the Working Group on Energy Policy (WGEP 1979) had highlighted the rural energy issues and also brought forth the absence of data on biomass energy use

In this study we have compiled and analyzed the data from the rural energy surveys conducted during 1985-92 to start the process of creating a rural energy database (REDB) and to identify regional variations in energy consumption pattern. Studies in the past have indicated that agro-climatic conditions are a important factor influencing the use of biofuels in rural areas. Both the level of biofuel use and the fuel-mix is believed to be influenced by the availability of different biofuels, which in turn, depends on the agroclimatic conditions. Consequently, we have post-stratified the biofuel consumption data according to agro-climatic regions specified by the Planning Commission (Planning Commission 1989). The results based on the analysis of the data compiled for 638 villages in 17 states spread over 14 of the 15 agro-climatic regions in the country have been discussed in Chapter 3 and are summarised in Table 4.1 (henceforth, these estimates are referred to as the "REDB estimates")

The analysis presented in Chapter 3 confirms the predominance of firewood and the analysis indicated the 95% confidence interval for per capita (pc) consumption (national aggregates) for cooking in the range of 1 10-1.34 kg/pc/d. The consumption of dungcake was lower -- the 95% confidence interval of the per capita consumption (national aggregates) was 0.40 - 0 49 kg/pc/d. The agricultural residue consumption was marginally higher with the 95% confidence interval range of 0 47 - 0 63 kg/pc/d. The REDB estimates indicate the that the per capita consumption across agro-climatic zones have a statistically significant variation across agroclimatic zones (see Chapter 3)

In addition to the data obtained by village level surveys sponsored by Government agencies responsible for energy programmes, the National Council for Applied Economic Research (NCAER) has carried out large scale surveys periodically. The domestic fuel survey of 1979 (NCAER 1985) covering 13,010 sample households spread over 18 states is the most prominent of the recent surveys of the NCAER. The rural sample for this survey was 7500 households selected from 300 districts in 600 villages and the state-wise summary (unfortunately, district-wise results were not presented in NCAER 1985) of the results are presented in Table 4.2 (henceforth estimates based on this data is referred to as the "NCAER estimates").

The other notable source of rural energy consumption data is from the Integrated Rural Energy Planning (IREP) exercise of the Planning Commission of the Government of India. This programme attempts to prepare and implement energy intervention plans for a administrative cluster of about 100-150 villages (termed as a Block) and involves sample surveys for determining energy consumption patterns as a part of this exercise. This programme was initiated during the Sixth Plan period (1975-80) on a pilot basis and since then (1985-92) has covered nearly 250 Blocks. Though information regarding the exact number of villages or households covered by the surveys are not available, the agro-climatic averages of the different biofuels used in the rural domestic sector are summarised in Table 4.3 (henceforth estimates based on this data is referred to as the "IREP estimates").

REDB and the IREP data is available for the different agro-climatic regions in India. The NCAER data, on the other hand, is restricted to state level averages. In the following sections attempt is made to estimate the rural biofuel use in the rural domestic energy sector aggregated at the state level based on the REDB, NCAER, and IREP data.

Method of estimating demand based on consumption surveys

The following steps were required for making estimates of the rural biofuel use.

1 Classification of districts according in the 15 agro-climatic regions

2 Identifying district average biofuel (firewood, dungcake, and agricultural residues) use based on the respective agro-climatic mean values for the REDB and the IREP estimates. Additionally, the REDB estimates contain the 95% confidence interval limits for respective agro-climatic zones (see Table 4.2), thereby resulting in three estimates -average and low and high limits based on the confidence interval limits. Estimates based on the IREP only use the mean values for the per capita biofuel consumption for the different agro-climatic zones (listed in Table 4 3) since these are the only information available

3 Using the 1991 census district-wise rural population (GOI 1992) and the per capita biofuel consumption (mean and the 95% confidence interval for the REDB estimates and the mean values for the IREP estimates) in which the district is located, the biofuel consumption is estimated.

4 The district-wise estimates of the biofuels are aggregated for the state for both, the REDB and the IREP estimates. The NCAER presented results aggregated at the state level. Therefore, the NCAER estimates use the 1991 state-wise rural population to estimate the state-wise biofuel consumption. Since the estimated biofuel need for the recommended energy requirements of the ESI, ABE, and EDSG use uniform levels (510, 620 and 520 kcal or 2.13, 2.60 and 2 18 MJ per capita daily, respectively) and fuels mix for the different states. the estimates of these can use the rural population at any level for the purpose of estimation. Though the results listed in Table 4 4 are aggregated at the national level for the sake of brevity, these were computed by using the state-level population for the sake of comparing aggregate of estimates based on surveys (REDB, IREP and the NCAER)

5 For all the estimates, the national aggregates are based on the sum of the state-wise aggregates

4.3 Results and conclusions

Table 4.4 summarises the useful energy consumption fulfilled by the biofuels in the rural domestic sector The national aggregated average useful energy consumption form biofuels alone is over 725 kcal pc.d about 3 MJ/pc.d) but there are significant variations among the agroclimatic regions (vindicating our rationale for post-stratification based on agroclimatic zones) The fuel-mix in the different agroclimatic regions is also presented in Table 4.4 It is interesting to note that the national aggregate relative fuel-mix indicated by the REDB data, 59 18 23 for firewood dung cake and agricultural residues is very close to the one used by ESI and the WGEP (65:15 20 for firewood dung cake and agricultural residues) The are however, noticeable difference between the agroclimatic zones in the fuel-mix For example Eastern Plateau and Hills has a very high per capita useful energy consumption (1264 kcal or 5 29 MJ) with a overwhelming part coming from firewood (93 0 7 for firewood dung cake and agricultural residues) In the Upper Gangetic plains, on the other hand. firewood accounts for less than 20% of the useful energy consumption 19·79 3 for firewood dung cake and agricultural residues

To date, very little attention has been devoted to the question of the fuel mix for meeting energy demand for rural areas Of the issues involving demand estimates different fuels (especially biofuels), the fuel mix issue is probably the most complex. This perhaps partially explains the inadequate importance placed to the fuel mix question despite its crucial role in determining a rural energy policy. Arguably, rural energy policy essentially requires specifying a fuel mix policy. The WGEP partially echoed this by stating that the question of and interventions to alter the existing fuel-mix were essentially macro policy decisions. Most Government policy documents in the past, however, looked at this issue with the intention of altering the existing fuel-mix to reduce the dependence of rural areas on biofuels. The premise for such assertion was that the non-commercial fuels (synonymous with biofuels) could be substituted by more efficient, cleaner and more convenient commercial fuels -- kerosene and soft coke for cooking and kerosene and electricity for lighting. Studies in the past indicate that interventions planned and formulated at such general level are rarely effective. For effective interventions in the existing energy supply system the major *energy related variable* is the level of scarcity (or surplus) of biofuels. The existing fuel-mix may be a useful indicator though a more rigorous study is required before this can be stated with confidence

The estimated national aggregate demand in physical units, based on NCAER, IREP, and the IREP estimated, for firewood, dung cake and agricultural residues are presented in Table 4.5 The table also summarises the necessary biofuel based on the normative levels of energy requirements of the ABE (1985), ESI (1965) (which is the same as the WGEP 1979) and the EDSG (1986) The most obvious feature of the different demand requirement estimates is the wide variation in the estimates The biofuel requirements for the recommended normative energy levels is in the range of 150-240 million tonnes/y of firewood, 40-65 million tonnes/y of animal waste and 47-76 million tonnes/y of agricultural residues The consumption levels indicated are in the range of 93-252 million tonnes/y of firewood, 54-107 million tonnes/y of animal waste and 36-99 million tonnes/y of agricultural residues The variation in the national aggregates higher if the 95% confidence interval of the REDB estimates are used

The national aggregates listed seems to give the impression that the REDB estimates are consistently higher In fact, the state-wise aggregates, presented in Table 4 6, indicate that there is no such clear pattern For example, the REDB estimates for firewood are higher largely due to the higher consumption in the states of Andhra Pradesh, Madhya Pradesh, Orissa, Tamil Nadu and West Bengal. The IREP estimates for firewood, on the other hand, are substantially higher for the states of Gujarat, Kerala, and Uttar Pradesh. Similarly, dungcake estimates of NCAER for Bihar and Madhya Pradesh are substantially higher than either the IREP or the REDB estimates.

Some of the likely reasons for these and the possible ways that a more consistent demand estimates can be made are as follows:

☐ NCAER data refers to the base period of 1979 whereas the IREP and REDB data are from the period 1985-91. Superficially, it would appear that biofuel use in rural areas has increased over time since NCAER estimates are consistently lower than either IREP or REDB data We believe, however, that the reason for this has to do more with the difference in the nature of data NCAER results are averages aggregated at state level while both, IREP and REDB averages are agro-climatic zone aggregates The relative closeness of IREP and REDB estimates suggest that there is a need to recast NCAER data according to agro-climatic regions which would require district wise classification of the surveys.

☐ Experience indicates that variations in the biofuel use is a inherent characteristic of energy systems based on biomass even within a agro-climatic region The need for a operational classification of agro-climatic regions makes it impossible to capture all factors which may influence biofuel consumption, particularly since the classification is based largely for planning agricultural development There is, therefore, a need to specify the statistical variation in data collected through surveys and to use these in making demand estimates so as to make different estimates comparable

☐ If the premise of the inherent variation in the biofuel use is accepted, there is a need to club all possible data and to thereafter estimate the mean values along with measures of the variation Collating data just from these three (NCAER, IREP and REDB) sources would result in a much richer database covering at least 3000 villages

Table 4.1. Summary of biofuel consumption in agroclimatic regions REDB estimates)

Firewood consumption (kc/pc/d)			
	Mean	95% confidence interval	
Western Himalayan zone	1.09	0.01	2.16
Eastern Himalayan zone	1.90	1.27	2.53
Lower Gangetic zone	0.93	0.38	1.47
Middle Gangetic zone	0.45	0.31	0.58
Upper Gangetic zone	0.29		
Trans Gangetic plains	0.38	0.29	0.46
Eastern plateau and hills	3.36	2.78	3.94
Central plateau and hills	0.95	0.65	1.24
Western plateau and hills	0.94	0.85	1.04
Southern plateau and hills	0.94	0.74	1.14
East coast plains and hills	1.78	1.25	2.31
West coast plains and ghats	0.94	0.71	1.18
Gujarat plains and hills	0.87	0.78	0.97
Western dry regions	0.57	0.36	0.78
All India averages	1.22	1.10	1.34

Dungcakes used for cooking (kg/pc/d)	Mean	95% confidence interval	
Western Himalayan zone	0.17	-0.27	0.61
Eastern Himalayan zone	0.20	0.01	0.38
Lower Gangetic zone	0.56	0.30	0.82
Middle Gangetic zone	0.41	0.32	0.50
Upper Gangetic zone	1.29		
Trans Gangetic plains	0.57	0.49	0.66
Eastern plateau and hills	0.01	-0.01	0.02
Central plateau and hills	0.65	0.44	0.86
Western plateau and hills	0.18	0.14	0.21
Southern plateau and hills	0.25	0.09	0.41
East coast plains and hills	0.91	0.16	1.65
West coast plains and ghats	0.16	0.01	0.31
Gujarat plains and hills	0.23	0.15	0.32
Western dry regions	0.61	0.45	0.77
All India average	0.40	0.32	0.49

Agricultural residues used for cooking (kg pc/d)			
Western Himalayan zone	Mean	95% confidence interval	
Eastern Himalayan zone	0.37	0.21	0.53
Lower Gangetic zone	0.62	0.24	1.01
Middle Gangetic zone	0.30	0.21	0.39
Upper Gangetic zone	0.04		
Trans Gangetic plains	0.34	0.26	0.42
Eastern plateau and hills	0.24	-0.03	0.51
Central plateau and hills	0.26	0.16	0.37
Western plateau and hills	0.50	0.43	0.56
Southern plateau and hills	0.82	0.05	1.58
East coast plains and hills	1.35	0.07	2.62
West coast plains and ghats	0.12	0.00	0.24
Gujarat plains and hills	0.31	0.20	0.41
Western dry regions	0.13	0.03	0.24
All India averages	0.47	0.32	0.63

Table 4.2. State-wise biofuel consumption in (NCAER estimates).

per capita daily in kg

State	Firewood	Dung cake	Agricultural residues
Andhra Pradesh	0.55	0.13	0.10
Arunachal Pradesh	0.31	0.00	0.20
Assam	0.31	0.00	0.20
Bihar	0.33	0.73	0.22
Goa	0.31	0.25	0.04
Gujarat	0.40	0.25	0.02
Haryana	0.14	0.70	0.21
Himachal Pradesh	1.31	0.02	0.00
Karnataka	0.60	0.02	0.14
Kerala	0.41	0.00	0.23
Madhya Pradesh	0.47	0.52	0.12
Maharashtra	0.31	0.25	0.04
Manipur	0.77	0.00	0.23
Meghalaya	0.77	0.00	0.23
Mizoram	0.77	0.00	0.23
Nagaland	0.77	0.00	0.23
Orissa	0.46	0.33	0.08
Punjab	0.25	0.58	0.32
Rajasthan	0.57	0.39	0.04
Sikkim	0.31	0.00	0.20
Tamil Nadu	0.47	0.11	0.11
Tripura	0.77	0.00	0.23
Uttar Pradesh	0.38	0.58	0.17
West Bengal	0.25	0.27	0.43
UNION TERRITORIES	0.25	0.36	0.17

Source: NCAER 1985

Table 4.3. Summary of biofuel consumption in agroclimatic regions (IREP estimates)

Agroclimatic zone	Firewood	Crop residue	Dung cake
Western Himalayan zone	1.95	0.14	0.22
Eastern Himalayan zone	1.70	0.00	0.00
Middle Gangetic zone	0.75	0.65	0.50
Upper Gangetic zone	0.36	0.35	0.43
Trans Gangetic plains	0.37	0.96	0.65
Eastern plateau and hills	1.60	0.00	0.00
Western plateau and hills	0.79	0.38	0.47
Southern plateau and hills	0.62	0.30	0.19
East coast plains and hills	0.60	0.08	0.13
West coast plains and ghats	1.29	0.21	0.00
Gujarat plains and hills	0.92	0.30	0.22
Western dry regions	1.08	0.03	0.44

Source: Computed from Planning Commission, 1992

Table 4.4. Useful energy consumption and fuel mix in different agroclimatic regions (REDB estimates)

Agroclimatic zone	Per capita useful energy		Fuel mix		
	in kcal/d	in MJ d	Firewood	Dungcake	Crop residues
Western Himalayan zone	436	1 83	0.87	0 13	0 00
Eastern Himalayan zone	860	3 60	0 77	0 07	0 15
Lower Gangetic zone	726	3.04	0 45	0 25	0 30
Middle Gangetic zone	397	1 66	0 39	0 34	0 26
Upper Gangetic zone	541	2 27	0.19	0 79	0 03
Trans Gangetic plains	440	1 84	0 30	0 43	0 27
Eastern plateau and hills	1264	5 29	0 93	0 00	0 07
Central plateau and hills	638	2 67	0 52	0 34	0 14
Western plateau and hills	562	2 35	0 59	0 10	0 31
Southern plateau and hills	697	2 92	0 47	0 12	0 41
East coast plains and hills	1393	5 83	0 45	0 21	0 34
West coast plains and ghats	426	1 78	0 78	0 12	0 10
Gujarat plains and hills	490	2 05	0 62	0 16	0 22
Western dry regions	448	1 88	0 45	0 45	0 10
All India	727	3 04	0 59	0 18	0 23

Table 4.5. National aggregates of biofuel use in rural domestic sector.

			in million t/y
	Firewood	Dungcake	Agricultural residues
Consumption			
NCAER	93.3	83.2	36.7
REDB (low)	181.3	40.1	31.6
REDB (average)	252.1	106.9	99.2
REDB (high)	309.4	114.5	165.5
IREP	169.0	54.2	62.8
Requirements			
ESI (510 kcal/pc/d or 2.13 MJ/pc/d)	151.3	41.5	47.8
EDSG (520 kcal/pc/d or 2.18 MJ/pc/d)	201.7	55.3	63.7
ABE (620 kcal/pc/d of 2.60 MJ/pc/d)	240.5	65.9	76.0

Table 4 6 State wise aggregates of biofuel use in rural domestic sector

in million t/y

State	Firewood			Dungcake			Agricultural residues		
	REDB Average	IREP	NCAER	REDB Average	IREP	NCAER	REDB Average	IREP	NCAER
Andhra Pradesh	23 2	10 8	0 74	0 5	2 9	2 20	18 6	3 6	1 75
Arunachal Pradesh	0 5	0 5	0 00	0 1	0 0	0 00	0 1	0 0	0 08
Assam	13 7	12 3	2 26	1 4	0 0	0 00	2 7	0 0	1 46
Bihar	34 1	26 9	8 90	8 2	9 9	19 89	7 8	13 0	5 99
Goa	0 0	0 0	0 08	0 0	0 0	0 00	0 0	0 0	0 01
Gujarat	8 6	0 1	3 09	2 3	2 2	2 47	3 0	3 0	0 23
Haryana	1 7	1 7	0 01	2 6	2 9	3 11	1 5	4 3	0 00
Himachal Pradesh	1 8	3 3	2 23	0 3	0 4	0 03	0 0	0 2	0 00
Karnataka	10 0	8 3	6 71	2 6	1 8	0 27	7 8	3 2	1 02
Kerala	7 1	10 0	3 19	1 2	0 0	0 00	1 0	1 6	1 78
Madhya Pradesh	32 6	13 1	8 68	6 2	1 8	9 62	5 7	1 5	2 32
Maharashtra	20 0	16 0	5 15	2 9	6 7	1 32	7 6	5 8	0 70
Manipur	0 0	0 8	0 37	0 1	0 0	0 00	0 2	0 0	0 11
Meghalaya	1 0	0 9	0 10	0 1	0 0	0 00	0 2	0 0	0 12
Mizoram	0 3	0 2	0 10	0 0	0 0	0 00	0 1	0 0	0 03
Nagaland	0 7	0 6	0 28	0 1	0 0	0 00	0 1	0 0	0 08
Orissa	26 0	11 2	4 56	1 3	0 6	3 43	7 6	0 4	0 76
Punjab	1 0	1 0	1 41	1 0	1 1	2 00	1 8	5 0	1 63
Rajasthan	9 8	1 3	7 05	7 8	2 1	1 76	2 8	0 8	0 51
Sikkim	0 3	0 2	0 01	0 0	0 0	0 00	0 1	0 0	0 03
Tamil Nadu	17 9	8 5	6 41	[illegible]	[illegible]	1 19	13 9	2 5	1 19
Tripura	1 6	1 4	0 66	0 2	0 0	0 00	0 3	0 0	0 29
Uttar Pradesh	16 6	21 0	15 56	[illegible]	[illegible]	[illegible]	5 6	17 3	6 98
West Bengal	20 3	4 1	1 52	9 0	0 0	1 85	10 5	0 0	7 71
UNION TERRITORIES	0 4	0 1	0 16	0 1	0 3	0 22	0 3	0 4	0 10
All India	[illegible]	109 0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CHAPTER 5

Conclusions and recommendations

The quality of the data and information presented in the survey reports are discussed in Chapter 2 and Chapter 3. As pointed out, the amount of information presented in the reports vary considerably. For instance, over 30% of the reports do not even mention the year of survey (Table 2.2 3). Over 20% of the reports do not have details of the land ownership and nearly half of the reports have no information on the energy use in agriculture (see Table 2.2.4). The geographical and the sectoral coverage of the data made available for this study is also uneven. The data on domestic sector is better than the data in other sectors Almost no information is provided on small scale industries and their energy requirements. The data on the energy input in agriculture, wherever collected, has wide variations in format. A note of caution, however, is required as far as the extent of information is concerned. The format in which data is presented for specific items vary widely as a result of which in many cases it is not possible to computerize all of these. For example, though energy use in agriculture is provided for a little over half of the villages, some reports present data aggregated for the village as a whole and aggregated for all the crops At the other extreme, some reports present crop-wise energy use (disaggregated for fuels along with break-up of animate energy used for different agricultural operations) for each village Clearly, standard formats for such wide variety of data is of little use Though these information have been collated and compiled, these have neither been computerized nor analyzed

The geographical unevenness in coverage is also noticeable. In the Upper Gangetic Zone only two village survey reports were available. Similarly, Western Himalayan Zone has only 5 survey reports and the Lower Gangetic Zone has only 7 village survey reports Inadequately covered states include Jammu & Kashmir (1 village), Kerala (2 villages), Himachal Pradesh (4 villages), Punjab (4 villages), Uttar Pradesh (8 villages), and West Bengal (7 villages)

Within these limitations, the following are the major conclusions from this study

Cooking

1 The energy consumption indicated by the survey reports collated are much higher than those indicated by previous studies. The all India averages of the estimated useful energy consumption is a little over 725 kcal (3.04 MJ) per capita daily. The normative recommended useful energy requirement has been in the range of 510 kcal or 2.13 MJ (ESI, 1965) to 620 kcal or 2.6 MJ (ABE 1985) per capita per day.

2 Though consumptions are high, there is a wide variation in energy use, both within as well as between agroclimatic regions The daily pre capita useful energy consumed varies between 397 kcal (1.66 MJ) to over 1390 kcal (5.83 MJ) for Middle Gangetic Plains and East Coast Plains and Hills, respectively Even within agroclimatic zones the variation is high.

3 The survey reports reconfirm the domination of biofuels in the rural energy system Within biofuels, firewood is the main fuel though its contribution among biofuels varies from barely 20% to over 80% in Upper Gangetic Plains and Eastern Plateau and hills

4 The use of biofuels, and hence the energy consumption due to the predominance of biofuels, is correlated to distance from main road, irrigation facilities, cattle to human ratio and electrification There appear to be a clear indication that with 'development' (as determined by the availability of irrigation facilities, electrification, and appearance of roads), the use of firewood goes down This is likely to be due to land-use changes though the lack of data in the surveys analyzed do not permit testing of this hypothesis

5 The fuel mix at country aggregate level close to past assumptions by the different studies (ESI 1965, WGEP 1979, ABE 1985, EDSG 1986) and are close to those indicated by the NCAER survey (NCAER 1985) However, at disaggregated levels such as the district or state levels there are significant variation due to variations in the fuel among agroclimatic regions (see Sinha and Joshi 1993 for a more detailed discussion). These differences also have very serious implications for aggregating biofuel demand at the country level and this has been illustrated in Chapter 4

6 The per capita cattle in a village appears to significantly effect the firewood consumption This is likely to be related to the availability of

biomass resources (both, firewood and fodder) particularly from forest and other common land. With increasing fraction of households in the village getting electrified, the per capita cattle present is lower Increasing irrigation appears to decrease the cattle population in the village. Electrification is likely to encourage the development of irrigation facility and a more intensive agriculture, discouraging high livestock population.

7 The use of agricultural residue and dung cake for energy purposes appears to depend on the level of firewood used -- the greater the firewood use, the less is the use of these 'safety-net' fuels The preference for firewood as a energy source is clear form the data. The dung cake use for cooking, however, appears to increase with irrigation This is possibly due to the increasing use of chemical fertilizers in irrigated areas which may conceivably result in release of dung for energy use Insufficient information on the use of chemical fertilizers in the surveyed villages, however, does not permit any conclusive statement in this regard.

8 Variation in the firewood used for cooking between agroclimatic regions has the highest degree of statistical significance The variation is widespread among agroclimatic regions with significant variation among almost all agroclimatic zones

9 Dungcake used for cooking has fairly significant variation among the agroclimatic zones The variation between agroclimatic Eastern Plateau, Trans-gangetic Plains Central Plateau, and Eastern Coast and Plains is significant Variation between Western Plateau and Eastern Coast and Plains is significant as is the variation between Eastern Coast and Plains and Gujarat Plains There is inconclusive variation between agroclimatic zones as far as agricultural residues used for cooking is concerned.

10 High reported use of kerosene for cooking in the Southern Plateau and hills is responsible for the noticeable variation The variation between the other agroclimatic zones is not statistically significant

Lighting

11 The energy use for lighting has noticeable variation between agroclimatic regions The variation between agroclimatic zones in the kerosene

used for lighting is very significant with the kerosene use showing statistically significant variation among almost all agroclimatic zones. Variation in the electricity used for lighting has similar statistical significance though the variation is not widespread among the agroclimatic zones.

12 With increasing distances from the main road the fraction of households electrified decrease as does the consumption of electricity. In relatively inaccessible villages more households own land but the decrease in the fraction of irrigated land is statistically significant.

Electrified villages have higher average kerosene use Electrification also encourages agro-industries and irrigation The number of landless households in electrified villages are higher indicating that economic disparities may be higher in villages electrified.

Recommendations

There are a large number of suggestions that the study team wishes to make as far as the conduct of surveys are concerned These range from where more effort at data gathering is required to the format in which these should be reported in survey reports We summarise some of the more important in the remaining part of this chapter

R1. The experience of compiling this database has highlighted a need for strengthening the capabilities of the field workers involved in data collection The accuracy of the data will depend on their appreciation of the issues and uncertainties in collection of data *We therefore strongly recommend efforts at human capability development through development of a training module for field level workers for collecting data.*

R2. The database needs to be strengthened in some agroclimatic zones and states Particular emphasis is required in the Upper Gangetic Zone, Western Himalayan Zone and the Lower Gangetic Zone

Inadequately covered states include Jammu & Kashmir Kerala Himachal Pradesh, Punjab, Uttar Pradesh, and West Bengal.

R3. The data on domestic sector is better than the data in other sectors This weakness needs to be removed in future data collection efforts Particularly, there is a need to include data on small scale industries and their energy requirements, in addition to strengthening the efforts to gather data on the energy input in agriculture.

R4. The aggregate estimate of biofuel consumption using data in the compiled data base varies from the other estimates such as the NCAER (1985), IREP (Planning Commission 1992), WGEP (1979), ABE (1984), and EDSG (1986). Of these, only NCAER and IREP estimate constitute demand based on consumption - the others are demands based on normative requirements. NCAER data refers to the base period of 1979 whereas the IREP and REDB data are from the period 1985-91. Superficially, it would appear that biofuel use in rural areas has increased over time since NCAER estimates are consistently lower than either IREP or REDB data. We believe, however, that the reason for this has to do more with the difference in the nature of data. NCAER results are averages aggregated at state level while both, IREP and REDB averages are agro-climatic zone aggregates. The relative closeness of IREP and REDB estimates suggest that *there is a need to recast NCAER data according to agro-climatic regions which would require district wise classification of the surveys.*

R5. If the premise of the inherent variation in the biofuel use is accepted there is a need to club all possible data and to thereafter estimate the mean values along with measures of the variation. Collating data just from these three (NCAER, IREP and REDB) sources would result in a much richer database covering at least 3000 villages. Therefore, *the computerised database should be made more comprehensive to include studies supported by other organisations.*

For this effort to be consistent, the responsibility of the task should be assumed by the Ministry of Nonconventional energy Sources (MNES). To start with, *the MNES should arrange for the computerisation of the IREP data in the format of the REDB. In parallel the process of recasting the NCAER data along the lines suggested above should also be initiated.*

It is imperative that the effort of creating the rural energy database is not viewed as a one time effort. Clearly *the data base should also be updated to include all new survey report and data on an annual basis.*

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ANNEXURE 1.1

gro-climatic regions of the Planning Commission and selected features of sub-regions.

Sl. No.	Subzone	Rainfall (mm)	Climate	Soils	Crops
	Western Himalyas				
1	High altitude temperature	165	Humid to cold arid	Hill soils, mountain meadow	Wheat, Maize, Rice, Jowar
2	Hill temperate	2000	Humid	Brown hill	Rice, Maize, Rapeseed, Wheat
3	Valley temperate	400	Sub-humid	Sub-mountain, mountain, meadow, skeletal.	Wheat, Maize, Rice, Sugarcane
4	Sub-tropical	1030	Semi-arid to humid	Alluvial (recent), brown hills	Wheat, Barley, Potato
	Eastern Himalayas				
1	Himalayan hills	2641	Per humid to humid	Red sandy, laterite	Rice, rapeseed, maize
2	NE hills	3528	Per humid to humid		
3	Southern hill	2052	Per humid to humid	Acidic soils	Rice, maize, seasamum, sugarcane
4	Lower Brahmaputra	1840	Per humid to humid	Alluvial, red loamy tarai soils	Rice, rapeseed, wheat, jute, potato
5	Upper Brahmaputra	2809	Humid to per humid	Alluvial, red loamy	Rice, jute, rapeseed, wheat
	Lower Gangetic plains				
1	Barind plains	1587	Moist sub-humid & dry	Red and yellow alluvial (recent)	Rice, jute, wheat, rapeseed
2	Central alluvial plains	1449	Moist sub-humid to dry sub-humid	Red and yellow, deltaic, alluvium, red loamy	Rice, jute, wheat, rapeseed, potato
3	Alluvial coastal saline pla	1607	Dry sub-humid to moist sub-humid	Red and yellow deltaic, alluvial	Rice, Jute, Rapeseed
4	Rarh plains	1302	Moit sub-humid to dry sub-humid	Red and yellow red loamy	Rice, wheat, rapeseed, sesamum
	Middle gangetic plains				
1	North-west alluvial	1211	Moist sub-humid to dry sub-humid	Alluvial (recent), calcareous	Rice, wheat, maize, sugarcane
2	North-west alluvial	1470	Dry sub-humid to moist sub-humid	Alluvial, tarai	Rice, wheat, maize, jute, gram
	Upper gangetic plains				
1	Central plains	979	Dry sub-humid to semi-arid	Alluvial	Wheat, rice, tur
2	North-western plains	907	Dry sub-humid to semi-arid	Alluvial tarai	Wheat, sugarcane, rice, maize
3	South-western plains	721	Semi-arid	Alluvial	Wheat, bajra, rice, maize, tur, potato

Sl. No.	Subzone	Rainfall (mm)	Climate	Soils	Crops
VI	Trans-gangetic plains				
1	Foothills of Shivalik & Him	890	Semi-arid to dry sub-humid	Alluvial (recent) calcareous	Wheat, rice, maize, sugarcane
2	Plains	561	Semi arid to Dry sub-humid	Alluvial (recent) calcareous	Wheat, rice, bajra, maize, sugarcane
3	Scarce rainfall arid zone	360	Arid & extreme arid	Calcareous, seirozemic alluvial (recent) desert	Wheat, cottong, gram, bajra, rice
VII	Eastern plateau and hills				
1	Eastern plain	1271	Dry sub-humid	Medium to deep black red and yellow	Rice, linseed, jowar, wheat, gram, gro
2	Eastern highland	1436	Moist sub-humid to dry sub-humid	Red sandy, red and yellow	Rice, maize, nigerseed, wheat
3	North central plateau	1296	Moist sub-humid to dry sub-humid	Red sandy, red and yellow	Rice, maize, ragi, wheat
4	Eastern plateau	1396	Moist sub-humid to dry sub-humid	Red and yellow, red loamy	Rice, maize, ragi, wheat
5	Tribal	1338	Moist sub-humid to dry sub-humid	Red sandy, red and yellow, red loamy laterite	Rice, ragi, nigerseed, maize
VIII	Central plateau and hills				
1	Bundelkhand (UP)	780	Dry sub-humid to dry arid	Mixed red and black	Wheat, gram, jowar, rice.
2	Bundelkhand (MP)	700	Dry sub-humid to Semi arid	Mixed red and black	Wheat, gram, jowar, rice
3	North hills	1570	Moist sub-humid to dry sub-humid	Red and yellow	Rice, wheat, nigerseed, maize
4	Kymore plateau and Satpura hills	1100	Dry sub-humid	Red and yellow medium black	Wheat, rice, gram, linseed
5	Vindhya Plateau	1130	Dry sub-humid	Medium black	Wheat, gram, jowar. rice
6	Satpura Plateau	1220	Dry sub-humid	Shallow black, mixed red and black	Jowar, Wheat, tur, rice
7	Central Narmada valley	1300	Dry sub-humid	Deep black, skeletal	Wheat, gram, soyabean, jowar
8	Gird	670	Semi arid (half drier and wetter)	Medium black, alluvial	Wheat, gram, jowar, rapesed, bajra
9	South-eastern plains	760	Semi arid (half drier and wetter)	Medium black	Wheat, jowar, gram, maize
10	Southern plains	760	Semi-arid (wetter half)	Medium red and black, grey, brown	Maize, rice, wheat, gram
11	Transitional plain	490	Semi-arid to arid	Desert soil, grey brown	Bajra, wheat, sesamum, rapeseed, jowar
12	Southern plains & Aravali hills	500	Semi-arid (wetter half)	Red and yellow, grey brown	Maize, wheat, gram jowar
13	Semi-arid eastern plains	500	Semi-arid (drier half)	Alluvial	Wheat, bajra, jowar, gram
14	Flood prone eastern plain	500	Semi-arid (drier half)	Alluvial (recent)	Bajra, wheat, repeseed, gram, jowar
IX	Western plateau & hills				
1	Hill zone	988	Semi-arid	Medium to deep black, shallow red, red loamy	Jowar, bajra, rice, groundnut
2	Scarcity zone	607	Semi-arid	Medium bloack, deep black	Jowar, cotton, wheat, gram
3	Plateau zone North	874	Semi arid (wetter half)	Medium black, deep black, mixed red and black, shallow red	Cotton, jowar, wheat, gram
4	Plateau zone South	1040	Semi-arid to dry semi-humid	Medium black, shallow black	Cotton, jowar tur, wheat

Sl. No.	Subzone	Rainfall (mm)	Climate	Soils	Crops
	Southern plateau & hills				Jowar, cotton, groundnut, bajra
1	Subzone 1	769	Semi-arid & arid	Medium black, laterite, deep black, red loamy	
2	Subzone 2	677	Semi-arid	Red loamy, medium black, red sandy, coastal alluviam,	Groundnut, ragi, jowar, rice laterite
3	Subzone 3	725	Semi-arid & arid	Red sandy, medium to deep black	Jowar, rice, catorseed, groundnut
4	Subzone 4	1001	Semi-arid (wetter half)	Deep black, medium black	Rice, jowar, maize, cotton, groundnut
5	Subzone 5	865	Semi-arid	Red loamy, red sandy	Ragi, Jowar, groundnut, rice
6	Subzone 6	841	Semi-arid to dry	Mixed red and black red	Rice, jowar, groundnut, bajra
I	East coast plains & hills		sub-humid	loamy, deltaic alluvium	
1	North Orissa coast	1287	Moist sub humid	deltaic alluvial, coastal alluvial laterite, red loamy	Rice, groundnut, jute, sesamum, ragi
2	North coastal Andhra	1128	Dry sub-humid	Red loamy, laterite, medium black red sandy, coastal alluvial	Rice, ragi, groundnut, bajra, sesamum
3	South coastal Andhra	996	Semi-arid	Deltaic alluvium, deep black red, sandy red and black	Rice, cotton, jowar, tobacco, groundnut
4	North coastal Tamil Nadu	1036	Sem-arid	red loamy, red sandy, coastal alluvium	Rice, groundnut, bajra, jowar
5	Tanjavur	1113	Semi-arid to dry sub-humid	Deltaic alluvium, red loamy	Rice, groundnut, sesamum, sugarcane
6	South coastal Tamil Nadu	780	Mixed red and black, coastal alluvium	Rice, cotton, bajra, groundnut	
I	West coast plains & ghats				
1	Coastal hilly	3640	Per humid & humid	Laterite, redloamy, coastal alluvium	Rice, ragi, sesamum, nigerseed
2	Coastal midland	3127	Dry sub-humid & per humid	Red loamy, coastal alluvium. laterite	Rice, tapioca, ragi, banana
3	Midland	2727	Per humid	Laterite, red loamy, coastal alluvium	Rice, tapioca, groundnut, banana
4	Hilly	2226	Per humid	Red loamy, mixed red and black	Rice, ragi, jowar, groundnut
III	Gujarat plains and hills				
1	South Gujarat A	1793	Semi-arid to dry sub-humid	Deep black, coastal alluvium	Rice, ragi, sugarcane, jowar
2	South Gujarat	974	Semi-arid to dry sub-humid	Deep black, coastal alluvium	Jowar, tur, cotton, wheat
3	Middle Gujarat	904	Semi-arid	Medium black	Rice, cotton, maize, bajra
4	North Gujarat	735	Arid tosemi-arid	Grey brown, coastal alluvium	Bajra, cotton, jowar, wheat
5	North-west arid	340	Arid to semi-arid	Grey brown, deltaic alluvium	Bajra, groundnut, jowar, cotton
6	North Saurashtra	537	Dry sub-humid	Medium black	Groundnut, cotton, bajra, jowar
7	South Saurashtra	844	Dry sub-humid	Coastal alluvium, medium blac	Groundnut, wheat, bajra, cotton
IV	Western Dry				
1	Western	395	Arid to extremely arid	Desert soil, grey brown	Bajra, gram, wheat, rapeseed

Source: Agrocilmatic regional planning: an overview, Planning Commission, Government of India, New Delhi, July 1989, pp.10-16.

ANNEXURE I.2

Characteristics of Some Typical Soil Series in Each Agro-ecological Region

Agro-ecoregion No.	Agro-ecoregion Name (Map Unit)	Area (m ha and %)	Physiography	Climate	Precip. (mm)	Land Utilization type	Forest Type	Soils Characteristics	Location District	Location State
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1.	Western Himalayas, Cold Arid Eco-Region (A13E1)	15.6 (4.7%)	Western Himalayas	Cold Arid	<150	Millets & Wheat (in Patches)	Snow Covered Most of the Time	Shallow, Sandy to Loamy, Skeletal Soils with Low AWC	Ladakh Keyland	Jammu & Kashmir Jammu & Kashmir
2.	Western Plain & Kutch Peninsula, Hot Arid Eco-Region (M9E1)	29.6 (9.%)	Eastern Plain & Kutch Peninsula	Hot Arid	<300	Millets & Pulses	Tropical Thorn Forest	Deep, Sandy & Coarse Loamy, Desert Soils with Low AWC & Deep, Loamy, Saline & Alkali Soil with Medium AWC	Pali Jaisalmer Bhuj	Rajasthan Rajasthan Gujarat
3.	Deccan Plateau, Hot Arid Eco-Region (K6E1)	4.7 (1.4%)	Deccan Plateau	Hot Arid	400-500	Millets Cotton & Oilseeds	Tropical Thorn Forest	Deep, Loamy Red Soils & Clay, Black Soils with Medium & High AWC	Raichur Anantpur	Karnataka Andhra Pradesh
4.	Northern Plain & Central Highlands, Hot Semiarid Eco-Region (N8D2)	32.9 (10.%)	Northern Plain & Central High Lands incluing Parts of Gujarat Plains	Hot Semi-Arid	400-800	Millets, Wheat, Pulses & Maize	Tropical, Dry Deciduous & Thorn Forests	Deep, Loamy, alluvium Derived Soils with Medium AWC & Shallow to Medium, Sandy to Loamy, Gray Brown Soils with Low to Medium AWC	Kapurthala Karnal Jaipur	Punjab Haryana Rajasthan
5.	Central Highlands (Malwa) Region) & Kathiawar Penninsula, Hot Semiarid Eco-Region (I5D2)	18.4 (5.6%)	Central (Malwa) Highland & Kathiawar Peninsula	Hot Semi-Arid	600-900	Millets, Wheat & Pulses	Dry Deciduous Forests	Medium & Deep, Fine Loamy & Clay, Black Soils with Medium & High AWC	Indore Indore	Madhya Pradesh Madhya Pradesh
6.	Deccan Plateau, Hot Semiarid Eco-Region (K4D2)	33.0 (10%)	Deccan Plateau	Hot Semi-Arid	600-1000	Millets, Cotton & Pulses	Tropical, Dry Deciduous & Thorn Forests	Shallow & Medium, Loamy to Clay, Black Soils with Low & Medium AWC; Inclusion of Deep, Clay Clay, Black Soil with High AWC	Ahmednagar Ahmednagar Sholapur	Maharashtra Maharashtra Maharashtra

Agro-ecoregion No.	Agro-ecoregion Name (Map Unit)	Area (m ha and %)	Physiography	Climate	Precip. (mm)	Land Utilization type	Forest Type	Soils Characteristics	Location District	Location State
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
7.	Deccan Plateau & Eastern Ghats, Hot Semiarid Eco-Region (K6D2)	20.8 (6.3%)	Deccan Plateau & Eastern Ghat	Hot Semi-Arid	600-1000	Millet, Rice & Oilseeds	Tropical, Dry Deciduous & Thorn Forests	Medium, Red Loamy Soils with Low & Medium AWC, & Deep, Clay, Black Soils with Medium & gh AWC	Medak Medak	Andhra Pradesh Andhra Pradesh
8.	Eastern Plateau & Deccan Plateau Hot Semiarid Eco-Region (H1D2)	22.7 (6.9%)	Eastern Ghats (TN Uplands & Deccan Plateau	Hot Semi-Arid	600-1000	Millets, Rice, Pulses & Oilseeds	Tropical, Dry Deciduous & Thorn Forests	Shallow to Deep, Loamy Red Soils, with Low to Medium AWC	Bangalore Coimbatore	Karnataka Tamil Nadu
9.	Northern Plain, Hot Subhumid Eco-Region (N8C3)	12.2 (3.7%)	Northern Plains	Hot Subhumid	1000-1200	Rice, Wheat, Pulses & Sugarcane	Tropical Moist Deciduous & Dry Deciduous Forests	Deep, Loamy, Alluvium-derived Soils with Medium & High AWC	Azamgarh Nainital	Uttar Pradesh Uttar Pradesh
10.	Central High Lands (Malwa & Bundelkhand), Hot Subhumid Eco-Region (I5C3)	8.2 (2.5%)	Central Highlands Malwa & (Bundelkhand)	Hot Subhumid	1000-1500	Wheat, Pulses & Millets	Tropical Dry Deciduous Forests	Medium & Deep Clayey, Black Soils with Medium & High AWC	Jabalpur	Madhya Pradesh
11.	Deccan Plateau & Central Highlands (Bundelkhand), Hot Subhumid Eco-Region (K6C3)	13.7 (4.2%)	Deccan Plateau & Central Highlands (Bundelkhand)	Hot Subhumid	1000-1500	Wheat, Millet, Cotton & Rice	Tropical Moist Deciduous Forests	Medium, Loamy, Red Soils & Medium & Deep, Clayey, Black Soils with Medium & High AWC	Chattarpur Nagpur Chattarpur	Madhya Pradesh Maharashtra Madhya Pradesh
12.	Eastern Plateau (Chattisgarh Region) & Eastern Ghats (Sambalpur (Region), Hot Subhumid Eco-Region (J1C3)	13.2 (4%)	Eastern Plateau (Chattisgarh Region)	Hot Subhumid	1200-1600	Rice, Millet & Pulses	Tropical Moist Deciduous Forests	Medium & Deep, Loamy, Red & Yellow Soils With Medium AWC	Sarguja Raigarh Sambalpur	Madhya Pradesh Madhya Pradesh Orissa
13.	Eastern Plateau (Chhota Nagpur Plateau) & Eastern Ghats (Sambalpur Region), Hot Sub-humid Eco-Region (J1C3)	27.8 (8.5)	Eastern (Chota Nagpur) Plateau & Eastern Ghats	Hot Subhumid	1000-1600	Rice, Pulses & Millets	Tropical Dry Deciduous & Moist Deciduous Forests	Shallow & Medium, Loamy Red Soils & Deep, Loamy Lateritic Soils with Low & Medium AWC	Santhal Paraganas Puri Jabalpur	Bihar Orissa Madhya Pradesh

Agro-ecoregion		Area				Land		Soils	Location	
No.	Name (Map Unit)	(m ha and %)	Physiography	Climate	Precip. (mm)	Utilization type	Forest Type	Characteristics	District	State
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
14.	Eastern Plain, Hot Subhumid Eco-Region (08C4)	9.3 (2.8%)	Eastern Plain	Hot Sub-humid	1400-1600	Rice, Wheat & Sugarcane	Tropical Moist Deciduous & Dry Deciduous Forests	Deep, Loamy, Alluvium-Derived Soils with Medium & High AWC	Bahraich Bhagalpur	Uttar Pradesh Bihar
15.	Western Himalayas, Warm Subhumid (inclusion humid) Eco-Region (A11C4)	17.7 (5.4%)	Western Himalayas	Warm Sub-Humid & Humid	1600-2000	Wheat, Millets, Maize & Rice	Moist Temperate Sub-tropical, Pine & Subalpine Forests	Shallow & Medium, Loamy, Forest & Podzolic Brown Soils With Low & Medium AWC	Srinagar Anantnag Kulu Manali	Jammu & Kashmir Jammu & Kashmir Jammu & Kashmir
16.	Assam and Bhopal Plains, Hot Humid Eco-Region (Q8B5)	11.7 (3.6%)	Assam & Bengal Plains	Hot Per-Humid	1400-2000	Rice, Jute & Plantation Crops	Tropical, Moist Decidusous & Dry Deciduous Forests	Deep, Loamy, Alluvium-derived with Medium & High AWC	Lakhimpur Hooghpur Jorhat	Assam West Bengal Assam
17.	Eastern Himalayas, Warm Perhumid Eco-Region (C11A5)	8.0 (2.4%)	Eastern Himalayas	Warm Per-Humid	2000-4000	Rice & Millets	Sub-tropical Pine, Wet Temperate Wet Evergreen & Subalpine Forests	Shallow & Medium Brown Red Hills Soils with Low AWC	Siang	Arunachal Pradesh
18.	North Eastern Hills (Purvachal), Warm Perhumid Eco-Region (D2A5)	10.7 (3.3%)	North Eastern Hills	Warm Per-Humid	1600-2600	Forests & rice in Patches	Wet Evergreen, Tropical, Moist, Deciduous & Wet Temperate Forests	Shallow & Medium, Loamy Red, Yellow & Lateritic Soils with Low AWC	West Manipur	Manipur
19.	Eastern Coastal Plains, Hot Subhumid Eco-Region (S7C5)	8.1 (2.5%)	Eastern Coastal Plain	Hot Sub-Humid	1200-1600	Rice & Millets	Littoral & Swamp Forests	Deep, Loamy, Coastal & Delatic Alluvial Soils with Medium & High AWC	Baleshwar Thanjavur	Orissa Tamil Nadu

Agro-ecoregion		Area	Physio-	Cli-	Precip.	Land	Forest	Soils	Location	
No.	Name (Map Unit)	(m ha and %)	graphy	mate	(mm)	Utilization type	Type	Characteristics	District	State
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
20.	Western Ghats & Eastern Coastal Plain, Hot, Humid to Perhumid Eco-Region (E2A6)	10.1 (3%)	Western Ghats & Coastal Plains	Hot Humid Per-Humid	2000-3200	Rice Tapioca, Coconut & Millets	Tropical, Moist Deciduous Forests	Shallow and Medium, Loamy, Red & Lateritic Soils with Low AWC & Deep, Coastal Alluvial Soils with High AWC	Trivandrum	Kerala
									Calicut	Kerala
21.	Islands Andaman-Nicobar & Lakshadweep Groups, Hot Perhumid Eco-Region (I1S6)	0.8 (0.3%)	Islands of Andaman & Nicobar & Lakshdweep	Hot Per-Humid	1600-3000	Forest, Coconut & Rice	Tropical, Wet Evergreen Littoral Swamp Forests	Medium & Deep, Red, Loamy & Sandy Soils with very Low to Medium AWC	Austinabad Sector	South Andaman
									Garacharma	Andaman Nicobar
									Sipi-	Andaman

Source: National Bureau of Soil Survey and Land Use Planning, Nagpur.

Annexure 2.1

Block-wise and District-wise number of surveyed villages analysed in this report

BLOCK	DISTRICT	Number of villages surveyed
Andhra Pradesh		33
Adilabad	Adilabad	1
Asifabad	Adilabad	1
Uravakonda	Anantapur	1
Agalimadakasira	Ananthapur	1
Thottambedu	Chittoor	1
Cuddapah	Cuddapah	1
Veerapunayunipalli	Cuddapah	1
Kirlampudi	East-Godavari	1
Rayavaram	East-Godavari	1
Maredumilli	East-Godavari	1
Sirisilla	Karim Nagr	1
Gundala	Khammam	1
Kunavaram	Khammam	1
Govardhangiri	Kurnool	1
Jupadubungalow	Kurnool	1
Maddikera	Kurnool	1
Gadwal	Mahaboob Nagar	1
Dubbak	Medak	1
Gajwal	Medak	1
Regode	Medak	1
[illegible]	Nalgonda	1
Nutankal	Nalgonda	1
Sullurpet	Nellore	1
Gandhari	Nizamabad	1
Rajendra Nagar	Rangareddy	1
Seethampeta	Srikakulam	1
Vazrapukothuru	Srikakulam	1
Bheemunipatnam	Visakhapatnam	1
Pendurthi	Visakhapatnam	1
Bondapalli	Vizianagram	1
Parvathipuram	Vizianagram	1
Denduluru	West-Godavari	1
Polavaram	West-Godavri	1

Assam		15
Mandia	Barpeta	1
Loharband	Cachar	[illegible]
Rajabajar	Cachar	1
Sonai	Cachar	1
Machkhowa	Dhemaji	1
Arearjar	Dhubri	1
Bilashipara	Dhubri	1
Np	Dhubri	1
Rongjulitribeldev	Goalpara	1
Sipahikholi	Jorhat	1
Northlakhimpur	Lakhimpur	1
Disangmukh	Sibsagar	1
Balipara	Sonitpur	1
Bihali	Sonitpur	1
Chayduar	Sonitpur	1

Bihar		[illegible]
Brahampur	Bhojpur	1
Charpokhari	Bhojpur	1
Koilwar	Bhojpur	1
Nabanagar	Bhojpur	1
Nabanagar	Bhojpur	1
Sahar	Bhojpur	1
Simri	Bhojpur	1
Simri	Bhojpur	1
Simri	Bhojpur	1
Udwant Nagar	Bhojpur	1
Udwant Nagar	Bhojpur	1
Udwant Nagar	Bhojpur	1
Gopikandar	Dumka	11
Dhaldhumgarh	Singhbhum	5
Dumaria	Singhbhum	5
Gamaria	Singhbhum	1
Kharswan	Singhbhum	1
Potka	Singhbhum	6
Seraikela	Singhbhum	1
Bathnaha	Sitamarhi	1
Belsund	Sitamarhi	1
Dumra	Sitamarhi	1
Nanpur	Sitamarhi	3
Parihar	Sitamarhi	2
Puri	Sitamarhi	1
Runisaiddpur	Sitamarhi	1
Sonewarsa	Sitamarhi	2
Sursand	Sitamarhi	2

Dhandhuka	Ahmedabad	1
Dholka	Ahmedabad	1
Amreli	Amreli	1
Jafrabad	Amreli	1
Deesa	Banaskantha	2
Deodhar	Banaskantha	4
Dhanera	Banaskantha	4
Np	Banaskantha	1
Radhanpur	Banaskantha	3
Vav	Banaskantha	2
Chhotaudepur	Baroda	3
Naswadi	Baroda	1
Amod	Bharuch	1
Ankleshwar	Bharuch	1
Bharuch	Bharuch	1
Dediapada	Bharuch	4
Nandod	Bharuch	1
Valia	Bharuch	1
Gadhada	Bhavnagar	1
Mahuva	Bhavnagar	1
Talaja	Bhavnagar	1
Dangs	Dangs	1
Jamjodhpur	Jamnagar	1
Khambhalia	Jamnagar	1
Okha	Jamnagar	1
Okhamandal	Jamnagar	1
Una	Junagadh	1
Talala	Junagarh	1
Visavdar	Junagadh	1
Balasinor	Kheda	1
Matar	Kheda	2
Mehmdabad	Kheda	1
Abdasa	Kutch	2
Anjar	Kutch	2
Bhachau	Kutch	2
Bhuj	Kutch	5
Lakhpat	Kutch	4
Mandvi	Kutch	3
Mundra	Kutch	2
Nakhatrana	Kutch	3
Rapar	Kutch	2
Kheralu	Mehsana	3
Vijapur	Mehsana	3
Dohad	Panchmahal	3
Godhara	Panchmahal	5
Jhalod	Panchmahal	5
Lunawada	Panchmahals	1
Santrampur	Panchmahals	1
Shehra	Panchmahals	1
Dhoraji	Rajkot	1
Morbi	Rajkot	2
Bayad	Sabar Kantha	1
Malpur	Sabar Kantha	2
Idar	Sabarkantha	3
Mandavi	Surat	2
Halvad	Surendranagar	1
Sayla	Surendranagar	1
Karjan	Vadodara	3
Sinor	Vadodara	1
Dharampur	Valsad	3
Navsari	Valsad	2
Pardi	Valsad	1

Haryana		61
Ambala	Ambala	2
Naraingarh	Ambala	2
Loharu	Bhiwani	1
Tosham	Bhiwani	1
Palwal	Faridabad	4
Gurgaon	Gurgaon	4
Nuh	Gurgaon	1
Hansi	Hisar	1
Jind	Jind	1
Narwana	Jind	2
Guhla	Kaithal	1
Rajound	Kaithal	1
Karnal	Karnal	1
Nilokheri	Karnal	2
Thanesar	Kurukshetra	3
Mohindergarh	Narnaul	1
Narnaul	Narnaul	2
Narnaul Chaudhari	Narnaul	1
Irana	Panipat	1
Madlanda	Panipat	1
Panipat	Panipat	1
Smalkha	Panipat	1
Rewari	Rewari	4
Jhajjar	Rohtak	3
Sampla	Rohtak	10
Baragudha	Sirsa	1
Ellanabad	Sirsa	1
Rania	Sirsa	1
Sirsa	Sirsa	1
Sonepat	Sonepat	1
Chhachh Rauli	Yamuna Nagar	4
Himachal Pradesh		4
Lambagaon	Kangra	1
Sunder Nagar	Mandi	1
Np	Solan	1
Hamirpur	Una	1
Jammu and Kashmir		1
Majalta	Udhampur	1

Karnataka 29

Anekal	Bangalore	1
Doddaballapur	Bangalore	1
Kanakapura	Bangalore	2
Belgaum	Belgaum	1
Hagaribommanahalli	Bellary	1
Sandur	Bellary	1
Bidar	Bidar	1
Hungund	Bijapur	1
Chitradurga	Chitradurga	2
Udupi	Dakshina Kannada	1
Navalgund	Dharwad	1
Ranebennur	Dharwad	1
Sakleshpur	Hassan	1
Gouribidanur	Kolar	1
Srinivasapura	Kolar	1
Mandya	Mandya	1
Kollegal	Mysore	1
Mysore	Mysore	1
Gangavati	Raichur	1
Raichur	Raichur	1
Thirthahally	Shimoga	1
Belthangady	South Kanara	1
Madhugiri	Tumkur	1
Tiptur	Tumkur	1
Turuvekere	Tumkur	1
Kumta	Uttara Kannada	1
Sirsi	Uttara Kannada	1

Kerala 2

Piravamthoor	Kollam	1
Np	Thiruvananthapuram	1

Madhya Pradesh 14

Mohkhed	Chhindwara	1
Bankhedi	Hoshangabad	1
Np	Jabalpur	1
Vijayraghavgarh	Jabalpur	1
Bichhiya	Mandla	1
Ambah	Morena	1
Narsingpur	Narsinghpur	1
Gotegaon	Narsingpur	1
Khilchipur	Rajgarh	1
Budhani	Sehore	1
Keolari	Seoni	1
Churhat	Sidhi	1
Kusumi	Sidhi	1
Vidisha	Vidisha	1

Maharashtra		91
Akole	Ahmednagar	1
Chandurrly	Amravati	1
Nandgaonkhandeshwar	Amravati	1
Aurangabad	Aurangabad	1
Lonar	Buldhana	2
Bhusawal	Jalgaon	1
Erandol	Jalgaon	1
Parola	Jalgaon	1
Gaganbawda	Kolhapur	1
Kagal	Kolhapur	1
Panhala	Kolhapur	1
Shirol	Kolhapur	1
Baglan	Nashik	1
Osmanabad	Osmanabad	1
Gangakhed	Parbhani	1
Jintur	Parbhani	1
Parbhani	Parbhani	1
Daund	Pune	1
Haveli	Pune	1
Khed	Pune	1
Purandhar	Pune	1
Velhe	Pune	1
Khatav	Satara	1
Mahabaleshwar	Satara	1
Satara	Satara	1
Akkalkot	Sholapur	2
Karmala	Sholapur	1
Malshiras	Sholapur	1
Devgad	Sindhudurg	1
Kudal	Sindhudurg	2
Bhivandi	Thane	1
Kalyan	Thane	1
Murbad	Thane	2
Shahapur	Thane	2
Vasai	Thane	1
Arvi	Wardha	7
Ashti	Wardha	7
Deoli	Wardha	6
Hinganghat	Wardha	6
Karanja	Wardha	7
Samudrapur	Wardha	6
Seloo	Wardha	6
Wardha	Wardha	6

Block		
Nilgiri	Balasore	4
G.Udayagiri	Bhulbani	1
Puintala	Bolangir	2
Sadar	Bolangir	2
Athagarh	Cuttack	1
Danagadi	Cuttack	2
Niali	Cuttack	1
Sukinda	Cuttack	2
Tangi Choudwar	Cuttack	2
Athmallik	Dhenkanal	3
Hindol	Dhenkanal	1
Kankadahad	Dhenkanal	2
Kanika G.P	Gangam	1
Kukudakhandi	Gangam	1
Rangeilunda	Gangam	2
Polsara	Ganjan	1
Bhawani Patna	Kalahandi	2
Kalampur	Kalahandi	1
Kesinga	Kalahandi	1
Koksara	Kalahandi	1
Banspal	Keonjhar	3
Harichandanpur	Keonjhar	2
Korukonda	Koraput	2
Jashipur	Mayurbhanj	2
Morada	Mayurbhanj	1
Rasgovindpur	Mayurbhanj	1
Chakapada	Phulbani	1
Harbhanga	Phulbani	2
K.Nuagam	Phulbani	1
Khajuripada	Phulbani	1
Phulbani	Phulbani	1
Astaranga	Puri	1
Balipatna	Puri	1
Chilka	Puri	1
Daspala	Puri	1
Gop	Puri	2
Khurda	Puri	1
Tangi	Puri	1
Jujumura	Sambalpur	1
Teleibani	Sambalpur	4
Banai	Sundargada	2
Banaigarh	Sundargarh	1
Koida	Sundargarh	1

Punjab		[illegible]
Dasuya	Hoshiarpur	1
Shahkot	Jalandhar	1
Kapurthala	Kapurthala	1
Sultanpur Lodhi	Kapurthala	1
Rajasthan		69
Arai	Ajmer	1
Jawaja	Ajmer	1
Kotasim	Alwar	1
Thanagazi	Alwar	1
Ghatol	Banswara	3
Chhipabard	Baran	1
Kishanganj	Baran	1
Barmer	Barmer	1
Chohtan	Barmer	1
Sheo	Barmer	1
Bayana	Bharatpur	1
Kaman	Bharatpur	1
Asind	Bhilwara	1
Jahazpur	Bhilwara	1
Mandalgarh	Bhilwara	1
Bikaner	Bikaner	2
Keshoraipatan	Bundi	1
Talera	Bundi	1
Chhotisadri	Chittaurgarh	1
Bhainsrorgarh	Chittorgarh	1
Bhopalsagar	Chittorgarh	1
Churu	Churu	1
Dungargarh	Churu	1
Rajgarh	Churu	1
Sardharshahar	Churu	10
Bari	Dholpur	1
Bichhiwara	Dungarpur	1
Simalwara	Dungarpur	1
Ganganagar	Ganganagar	1
Padampur	Ganganagar	1
Raisinghnagar	Ganganagar	1
Chaksu	Jaipur	1
Jhotwara	Jaipur	2
Sam	Jaisalmer	3
Sanchore	Jalore	1
Khanpur	Jhalawar	1
Pirawa	Jhalawar	2
Palodi	Jodhpur	1
Chhipabarod	Kota	1
Deedwana	Nagaur	1
Nagaur	Nagaur	1
Raipur	Pali	1
Amet	Rajsamand	1
Kumbhalgarh	Rajsamand	1
Mahuwa	Sawaimadhopur	1
Sapotra	Sawaimadhopur	1
Sawaimadhopur	Sawaimadhopur	1
Malpura	Tonk	1
Tonk	Tonk	2
Uniara	Tonk	1
Bhinder	Udaipur	1
Rajsamand	Udaipur	1

Tamil Nadu

Athur	Anna	1
Palani	Anna	1
Pazhal	Chengalpat	1
Kattangulathur	Chengalpattu	2
Uthiramerur	Chengalpattu	1
Ottapidaram	Chidambaranar	1
Srivaikundam	Chidambaranar	1
Thiruchendur	Chidambaranar	1
Thiruporur	Chingleput	1
Karamadai	Coimbatore	1
Perianaickenpalayam	Coimbatore	1
Harur	Dharmapuri	3
Virudhunagar	Kamarajar	3
Agasteeswaram	Kanyakumari	1
Kurunthangodu	Kanyakumari	2
Thirumangalam	Madurai	2
Alangulam	Nellai Kattabomman	2
Nanguneri	Nellai Kattabomman	1
Wallajah	North Arcot	2
Kalayarkoil	Pasumpon Muthuramalingam	1
Sivaganga	Pasumpon Muthuramalingam	1
Thirupathur	Pasumpon Muthuramalingam	2
Dharapuram	Periyar	1
Perunthurai	Periyar	1
Avudiyarkoil	Pudukkottai	1
Manamelkudi	Pudukkottai	1
Bogalur	Ramanathapuram	1
Kadaladi	Ramanathapuram	1
Mudukalathur	Ramanathapuram	1
R.S.Mangalam	Ramanathapuram	1
Thiruppullani	Ramanathapuram	1
Ayothyapattinam	Salem	1
Kadayampatti	Salem	1
Thiruchengodu	Salem	1
Gingee	South Arcot	1
Melmalayanur	South Arcot	1
Np	South Arcot	1
Thiyagadurgam	South Arcot	1
Viruddhachalam	South Arcot	1
Orathanadu	Tanjor	1
Myiladuthurai	Tanjor	1
Nagapattinam	Tanjor	1
Vedaranyam	Tanjor	1
Andhanallur	Trichy	1
Musiri	Trichy	1

Uttar Pradesh

8

Mohinpurwa	Bahraich	1
Mankapur	Gonda	1
Bhathat	Gorakhpur	1
Paniyara	Gorakhpur	1
Chirgaon	Jhansi	2
Rampurkhas	Pratapgarh	1
Chamraua	Rampur	1

West Bengal

7

Khejuri-II	Midnapur	4
Amdanga	North 24 Paraganas	1
Bagdah	North 24 Parganas	1
Barrackpore	North 24 Parganas	1

Annexure 2.2

List of variables

Label	Description
AGENCY	Agency Name
AGL_PC	Ag-land/Pop (ha /pc)
AGRO_C	Agro-Climatic Zone
AGRO_I	No of agro-industry (Nos)
AGR_COK	Agriculture residues for cooking (kg/p/d)
AGR_ENR	Energy use in agriculture provided (Y/N)
AG_LAND	Agricultural land (ha)
AG_PRCE	Agricultural residues (Rs/kg)
ANIMT_E	Animate energy consumption (Y/N)
AREA_PC	T-area/Pop (ha /pc)
BLOCK	Block
CATLE	No of main cattle (All Age) (Nos)
CATLE_A	No of main cattle, adult (Nos)
CATLE_O	No of other cattle (Nos)
CON_ELE	Electricity consumption per unit (kWh/d)
CON_HSD	Diesel consumption per unit (l/d)
CRP_YLD	Crop yields provided (Y/N)
C_FERTS	Use of chemical fertiliser (Y/N)
C_H_RATIO	Catle/Pop (Nos /pc)
DC_COK	Dungcake for cooking (kg/P/d)
DC_PRCE	Dungcakes (Rs/kg)
DISTR	District
DIST_MR	Distance from main road (Km.)
DIST_PHC	Distance from P H C (Km.)
DS_PRCE	Diesel (Rs/l)
D_PUMP	No of diesel pumpset (Nos)
ELECTRI	Electrified (Y/N)
ELEC_HH	No of electrified household (Nos)
ELEC_HH%	Pecentage of households electrified (percentage)
ELEC_LI	Electricity for lighting (kWh//hh/d)
E_PUMP	No of electric pumpset (Nos)
FW_PRCE	Firewood (Rs/kg)
F_WOD_C	Firewood for cooking (kg/P/d)
GOAT	No of Goat/Sheep (Nos)
HANDPMP	No of handpumps for drinking water (Nos.)
HHNum	No of household (Nos)

Contd

List of variable (Contd.)

Label	Description
IN_CAP	Capacity of prime-mover of agro industry (kW)
IRR_L%	Irrigated land as a percentage of agricultural land
KO_PRCE	Price of kerosene (Rs/l)
KOiL_CO	Kerosene for cooking (l/P/d)
KOiL_LI	Kerosene for lighting (l/hh/d)
LAN_CAT	Information on other land category provided (Y/N)
LAN_LES	No. of landless household (Nos)
LAN_LES%	Landless households as a fration of total
LAN_O	Catagries of land owned provided (Y/N)
LAN_O%	Landowning households as a fraction of total
LAN_OWN	No of land owners (Nos)
OTH_PRC	Prices of other commodities provided (Y/N)
POP	Population (Nos)
SCH_TY	Type of highest school (P/M/H)
SEAS_V	Seasonal variation provided (Y/N)
SPACE_H	Space heating (Y/N)
STATE	State
SUR_HH	No of surveyed house holds (Nos)
SUR_HH%	Surveyed households as a percentage of total households
THRSHER	No of threshers (Nos)
TOT_SCH	Total no of school (Nos)
TRACTOR	No of tractors (Nos)
T_AREA	Total area (ha)
T_IRR_L	Total irrigated land (ha)
VILL	Village
WATER_H	Water heating (Y/N)
WELLS	No of wells for drinking water (Nos)
YEAR	Year of Survey

Annexure 2.3

Assumptions in compiling the data

The villages in the newly formed districts were included in the appropriate agro-climatic zones by referring to the map.

Dungcakes: The weight of a dungcake is assumed as 200gm In cases where information could not be converted, it is compiled as not provided.

Pumpsets: In some reports the type of pumpset was not specified We have assumed them to be electric in the electrified villages and diesel in the non-electrified villages This may lead to over estimation of electric pumpsets and under estimation of diesel pumpsets.

Land Most reports gave data on total area of the village and agricultural land Many did not specify other categories of land

In a few villages, the agricultural land is found to be more than the village land. This could be due to different data sources or wrong categorisation eg the land cultivated by the villagers in a village may be more or less than the agricultural land in the village due to the leasing practices This doesn't seem to have been accounted for

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